CATALOGUE

OF THE

BLASTOIDEA

IN THE

GEOLOGICAL DEPARTMENT

OF THE

BRITISH MUSEUM
(NATURAL HISTORY),

WITH AN ACCOUNT OF THE MORPHOLOGY AND SYSTEMATIC POSITION OF THE GROUP, AND A REVISION OF THE GENERA AND SPECIES.

(ILLUSTRATED BY 20 LITHOGRAPHIC PLATES, &c.)

BY

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AND

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PREFACE.

When the Authors of the present work commenced their task of monographing this curious and extinct group of Echinodermata, they did not contemplate the production of an official publication, but a Memoir on the Blastoidea to be presented to one of the learned Societies.

As their illustrations had, however, been largely taken from specimens in the British Museum, it was suggested that the work should be submitted to the Trustees to appear as one of the series of Museum Catalogues.

At this time sixteen of the twenty Plates illustrating the work had already been drawn upon stone and paid for out of the Government Grant Fund of the Royal Society. These Plates were, however, with the approval of the Council, transferred to the Trustees, at whose cost they have been printed off, and also four additional Plates drawn and added to the series, together with seven illustrative woodcuts.

Science is greatly indebted to the Authors for their very careful and patient labours, not only in the study and comparison of external forms both of recent and fossil Echinodermata, but in preparing sections showing the internal structure of these organisms, involving long and patient examination with the microscope, by means of which they have been largely assisted in working out the morphology of this obscure and but little understood group.

HENRY WOODWARD,
Keeper of the Department of Geology.

British Museum (Natural History),
July 1st, 1886.

AUTHORS' PREFACE.

The present work is the result of our joint study of the Blastoidea, which has been carried on for the past seven years, though with a considerable amount of interruption owing to our official duties and to the pressure of other engagements. It originated in a strong desire to investigate the structure and relationships of this interesting group of extinct Echinoderms by the light of the recent advances in our knowledge of their living representatives.

The additions to our knowledge of Echinoderm structure which we owe to the genius of Johannes Müller no doubt largely influenced Professor Ferdinand Roemer when preparing his classical work on the Blastoidea, which is now more than thirty-five years old, and must be regarded by all as a model of precise and accurate descriptive Palæontology.

But recent discoveries have furnished so much additional information as to the relationships of the Stalked Echinoderms, that they are now viewed in quite a different light from that which was shed upon them by Müller's memorable researches. Under these circumstances, the interest attached to a renewed morphological investigation of the Blastoidea attracted us very strongly. Our chief difficulty, the want of adequate material, was soon and simply solved; for Mr. Charles Wachsmuth, of Burlington, Iowa, whose admirable work on the Palæocrinoids is known to every palæontologist, generously offered to place at our disposal a selected series from his fine collection of American Blastoids, which should be specially adapted for the exhibition of structural characters.

The collection reached us in April, 1881; and though it was originally lent for six months only, the owner's liberality has enabled it to remain in our hands for over five years. Nothing that we can say can express better than this statement the extent of our indebtedness to Mr. Wachsmuth's generosity, which prompted him to expose a valuable collection to a double journey across the Atlantic and a prolonged detention in this country, in the hope of promoting scientific knowledge. We wish that we could regard the results of our work as at all commensurate with our feeling of indebtedness to Mr. Wachsmuth, with whom we are sorry to find ourselves at variance upon certain morphological questions. But it is perhaps scarcely

to be expected that there should be a complete concordance of opinion between workers who approach the subject from altogether different sides; and the discovery of the truth, which is the ultimate object of us all, can only be attained by a combined investigation along several converging lines of inquiry.

Besides providing us with material, Mr. Wachsmuth has also been kind enough to keep us informed from time to time of the progress of his own researches, and in some instances these have led to the abandonment or modification of views which we had previously expressed. Thus, for example, we did not become fully aware until the end of last year that the Silurian *Troostocrinus Reinwardti* must be separated generically from most of the Carboniferous species usually referred to this genus; and it was not till March last that we learnt of Mr. Wachsmuth's most important discovery that *Stephanocrinus* is not a Blastoid at all, but a Brachiate Crinoid. The earlier sheets of this work, therefore, contain many passages which would have been differently expressed had we known as much when they were written as we do now. But we are indebted to Mr. Wachsmuth's kindness for the opportunity of modifying our earlier statements in the later portion of the Catalogue, and we can now only tender him our most sincere thanks for the very free use which he has allowed us to make of his unpublished observations. (See pp. 118, 196.)

We have also to express our gratitude to the many other scientific friends, both at home and abroad, for the ready way in which they have facilitated our work, either by the gift, exchange, or loan of specimens, or by valuable information of various kinds. We would mention especially Professor W. H. Barris, of Davenport, Iowa; Mr. R. R. Rowley, of Curryville, Missouri; Professor A. H. Worthen, of Springfield, Illinois; Messrs. S. A. Miller and A. G. Wetherby, of Cincinnati; and Mr. E. N. S. Ringueberg, of Lockport. Don Lucas Mallada, of Madrid; Professors L. G. de Koninck and G. Dewalque, of Liége; Prof. F. Roemer, of Breslau; M. Munier-Chalmas of Lille; and Professors Albert Gaudry and E. Perrier, of Paris, have all been kind enough to supply us with valuable material; and we have been similarly favoured nearer home by Dr. A. Geikie, Director-General of the Geological Survey of Great Britain; Mr. J. Bennie, of Edinburgh; Prof. H. A. Nicholson, of Aberdeen; Prof. T. McKenny Hughes, of Cambridge; Prof. W. J. Sollas and Mr. W. H. Baily, of Dublin; Prof. W. Boyd Dawkins, of Manchester; Dr. G. J. Hinde, of Mitcham; Rev. G. Style, of Giggleswick; Rev. G. F. Whidborne, of Torquay; and Mr. D. Geddes, of Blackburn. All these gentlemen have responded to our inquiries with the most liberal kindness, and we therefore take this opportunity of expressing our thanks to them for their help.

The material lent us by these gentlemen and from other sources has furnished 89 figures, in addition to the 72 figures drawn from Mr. Wachsmuth's collection; while 178 specimens illustrated by 245 figures are in the National Collection. The latter contains representatives of all the nineteen genera of

Blastoidea, except the rare *Pentephyllum* and *Eleutherocrinus*, though the former type is illustrated by a cast of the only known specimen, which belongs to the Museum of the University of Dublin. As the National Collection also contains a good series of the American Blastoids, and numerous representatives of those found in France, Spain, Belgium, and Germany, together with the valuable collections made by Rofe and Gilbertson from the Carboniferous Limestone of Lancashire and Yorkshire, we have no hesitation in saying that it is not only unrivalled, but that it is not likely ever to be surpassed in the completeness of its collection of Blastoidea. For the localities where Rofe and Gilbertson obtained their specimens are no longer so productive as they were, and neither Blastoids nor Crinoids can now be procured so easily as was the case even up to twenty years ago.

We have further specially to acknowledge the generous aid which has been afforded to us by the Council of the Royal Society, who placed at our disposal in 1881 a sum of money from the Government Grant Fund, to assist us in adequately illustrating our work; we are also indebted to them for allowing the sixteen Plates which had been paid for out of that fund to be published in a volume issued by the Trustees of the British Museum. These Plates, together with the four which have been since drawn, are the work of our friends, Messrs. Charles Berjeau, F.L.S., and Percy Highley; and we find it difficult to express our appreciation of the care and zeal with which they have performed a very important share of our joint work.

The arrangement of the Plates has been necessitated by circumstances. The material which is now at our disposal was not all in our hands when the earlier Plates were drawn, but has reached us at intervals during the progress of our researches; and the consequence is that the figures illustrating some specific forms are scattered over several Plates, instead of being concentrated on one or two, as they would have been had we been able to collect all our material before commencing our illustrations.

We have endeavoured, so far as it has been in our power, to make the present work a monograph of all described Blastoidea; but we have found ourselves obliged to leave it incomplete at many points. There are very few European Blastoids, probably not half a dozen in all, which we have not studied; and by the kindness of Mr. Wachsmuth and of other friends in America we have been enabled to examine one or more species of all the genera which occur in that country. But there are still many species about which little is known. In some cases this is due to the rarity of the literature concerning them, and in others to the want of adequate descriptions or figures. In many cases, too, we are in great uncertainty as to the stratigraphical position of a species, owing to a want of precision or of accurate geological information on the part of its describer. These are questions which can only be satisfactorily solved on the spot, and we must therefore leave them in the hands of our

American fellow-workers, in the hope that one of them will undertake a critical revision of the American species of Blastoidea. We would further express the hope, however, for the sake of our successors, that this work will not be attempted by any mere collector, however zealous, and no matter how many thousand specimens his cabinet may contain, but by a trained palæontologist who is acquainted with the principles of morphology in general, and with that of the Echinoderms in particular. For we feel very strongly that unless systematic Palæontology is based upon Morphological principles its results are not likely to have any permanent value; and we could wish that some of Roemer's successors had realized this fact as clearly as he did himself.

R. ETHERIDGE, Jun.
P. HERBERT CARPENTER.

Department of Geology, British Museum
(Natural History),
June, 1886.

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P. 43, line 26. For *Pentremites robustus* read *Pentremites hemisphericus.*

P. 48, lines 13, 18. For *P. Godoni* read *P. Burlingtonensis.*

P. 94, line 21. For *P. Godoni* read *P. Burlingtonensis.*

P. 123, line 3 from the bottom. For *G. McCyi* read *G. McCoyi.*

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P. 169, line 5. For *Pentremitidea* read *Pentremitidæa.*

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CATALOGUE

OF

THE BLASTOIDEA.

CHAPTER I.

THE ZOOLOGICAL HISTORY OF THE BLASTOIDEA.

The name "Blastoidea" was proposed by Thomas Say[1] in the year 1825 for a group of Echinoderms which was clearly recognized by him as distinct from the family "Crinoidea" established by Miller four years previously[2].

The zoological families of that date correspond in many cases to the classes of more modern systems, just as many of the so-called genera established by Miller are now the types of large families of Crinoids, the latter group itself being almost universally recognized as a class of the subkingdom Echinodermata. But its limits have been extended by many authors so as to include forms to which Miller's original definition is by no means applicable. According to this definition, the cup-like body containing the viscera of a Crinoid bears on its upper rim "five articulated arms, dividing into tentaculated fingers, more or less numerous."

Although, from his knowledge of Parkinson's 'Organic Remains of a Former World,' Miller must have been aware of the existence of the "Asterial Fossil"[3] (the *Encrinus Godoni* of De France[4], or *Pentremites* of Say and later writers),

[1] "On two new Genera and several Species of Crinoidea." Journ. Acad. Nat. Sci. Philad. 1825, vol. iv. pt. 2, p. 293.

[2] A Natural History of the Crinoidea (Bristol, 1821), p. 7.

[3] Organic Remains of a Former World (London, 1808), vol. ii. p. 235, pl. xiii. figs. 36, 37.

[4] Dictionnaire des Sciences Naturelles (Paris, 1819), vol. xiv. p. 467.

he never included it in his family Crinoidea, to which it has been so often referred by his successors. It has a jointed column which supports a cup-like body containing the viscera, just as in *Platycrinus*; but this cup bears no arms, and it is clear that their absence was regarded by Miller as a sufficient reason for not including the Pentremite type among the Crinoidea.

Say [1] remarked in like manner:—"By its columnar support it is related to the family Crinoidea, but the total absence of arms and hands excludes it from that very natural group;" and he therefore described the Blastoids as a new family of Echinoderms occupying an intermediate position between the Crinoidea and the Echinoidea, with which last group he imagined *Pentremites* to have some affinities. This was perhaps due to his thinking it highly probable that "the branchial apparatus communicated with the surrounding fluid through the pores of the ambulacræ by means of filamentous processes" [2].

Later researches have shown, however, that Say and many subsequent writers were almost certainly wrong in this supposition. But while the imaginary affinity of the Blastoids with Echini has thus received a certain amount of support, their fundamental difference from the Crinoid type has been in no way lessened; and the results of recent investigations into the structure of both groups fully bears out Say's remarks upon the subject.

His description of the "Kentucky Asterial Fossil," under the generic name *Pentremite* [3], led to the establishment of several new species during the next twenty-five years by Sowerby, Phillips, and M'Coy in this country; by Bronn, Goldfuss, De Koninck, Münster, and De Verneuil in continental Europe; and by Troost, Yandell, and Owen and Shumard in America. A new generic type was recognized by Troost and by Conrad in America (*Olivanites*, Troost, MS., =*Nucleocrinus*, Conrad, =*Elæacrinus*, Roemer [4]); and another, which was recognized by Conrad and described by himself and by Hall [5] under the name of *Stephanocrinus*, was placed by Ferdinand Roemer [6] among the Cystidea, a proposal in which we cannot agree. In this country, too, *Astrocrinites* and *Codaster* were described by the Messrs. Austin [7], and M'Coy [8]

[1] *Loc. cit.* p. 292. [2] *Ibid.* p. 296.

[3] "Observations on some Species of Zoophytes, Shells, &c., principally fossil." American Journ. Sci. 1820, vol. ii. p. 36.

[4] "Monographie der fossilen Crinoidenfamilie der Blastoideen, und der Gattung Pentatrematites im Besondern." Archiv f. Naturgesch., 1851, Jahrg. xvii. Bd. i. p. 375.

[5] Palæontology of New York, vol. ii. (Albany, 1851), p. 212.

[6] "Ueber *Stephanocrinus*, eine fossile Crinoiden-Gattung aus der Familie der Cystideen." Archiv f. Naturgesch. 1850, Jahrg. xvi. Bd. i. pp. 365–375, Taf. v.

[7] "Proposed Arrangement of the Echinodermata, particularly as regards the Crinoidea, and a subdivision of the Class Adelostella (Echinidæ)." Ann. & Mag. Nat. Hist. 1842, vol. x. p. 112.

[8] "On some new Palæozoic Echinodermata." *Ibid.* 1849, vol. iii. p. 250.

respectively. These are all well-defined generic types, and have been since recognized as valid. But in 1849 D'Orbigny[1] established the genus *Pentremitidea* for two Spanish Blastoids in which he supposed deltoid pieces to be absent. Roemer[2] showed, however, that D'Orbigny was here in error; and the genus consequently fell into disuse till it was revived by ourselves in 1882 with a more precise definition[3].

During the first half of the present century the morphology of the Blastoids seems to have attracted but little attention. Roemer[4] discovered the so-called pinnules of *Pentremites* in 1848; and two years later Owen and Shumard[5] announced the discovery of *Pentremites* with the summit-opening closed by plates. Except in these points, however, hardly anything was added to our knowledge of the morphology of the Blastoidea, Goldfuss (the chief German palæontologist) being led astray by their supposed resemblance to the Echinoidea; while the descriptions of new genera were of the most superficial nature, with scarcely any foundation of anatomical facts.

In the year 1852, however, all this was changed by the publication of Roemer's classical monograph[6] of the Blastoidea, and of the *Pentremites* in particular. Several new species of this genus were described and the existing ones re-defined; while it was divided into four sections, each with its typical species. The careful discrimination exercised by Roemer in this classification is strikingly manifested by the fact that each of the specific types employed by him in this way is now regarded as representing a distinct genus; while three other genera have been established for the reception of species such as *Pentremites caryophyllatus*, De Koninck, *P. obliquatus*, Roemer, sp., and *P. pentangularis*, Miller, sp., which were respectively placed by Roemer in the first three sections of the genus, but with a "query" attached in each case. Roemer further gave an elaborate diagnosis of a very remarkable type, *Elæacrinus*, which had been distinguished by both Conrad and Troost as generically distinct from *Pentremites*, though neither author had ever given a proper description of it.

Important, however, as was Roemer's contribution to the systematic arrangement of the Blastoidea, it was altogether eclipsed by his great additions to our knowledge of their morphology. He gave a careful analysis of the three groups of plates forming the calyx of a Blastoid, and was the first who clearly showed the relation

1 Cours élémentaire de Paléontologie et de Géologie stratigraphique. 1852, vol. ii. p. 139.

2 Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 369.

3 "On certain Points in the Morphology of the Blastoidea, with Descriptions of some new Genera and Species." Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 220.

4 "Ueber gegliederte, aus Kalkstückchen zusammengesetzte Tentakeln oder Pinnulæ auf den sogenannten Ambulacral-Feldern der Pentremiten." Neues Jahrb. f. Mineral. 1848, pp. 292–296.

5 "Descriptions of Fifteen new Species of Crinoidea from the Sub-Carboniferous Limestone of Iowa, collected during the U.S. Geological Survey of Iowa, Wisconsin, and Minnesota in the years 1848–49." Journ. Acad. Nat. Sci. Philad. 1850, vol. ii. part 1, p. 65.

6 Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. pp. 323–397, Taf. i.–v.

of the so-called deltoid plates to the summit-openings; while he laid the foundation of a scientific study of the various ambulacral structures, and discovered the remarkable complex organs which lie beneath them, now generally known as the hydrospires. There can be little doubt, too, that he was correct in assigning a generative function to this apparatus and to the summit-openings, though it is probable that they had other functions as well.

Roemer concluded with a reference to the systematic position of the Blastoidea. Although he placed them in the order Crinoidea, he recognized, as Say [1] had previously done, that they agree with the Cystids and differ from the true Crinoids in the absence of arms. Unaware of the excellent name "Pelmatozoa" proposed by Leuckart [2] four years previously for the three groups of stalked Echinoderms, Roemer, like many other naturalists, extended the name Crinoidea to include the armless forms; and, regarding it as of ordinal value, he considered the Blastoids, Cystids, and Brachiate Crinoids as equivalent families or sections of the order. The principles of Roemer's classification have been very generally adopted both in this country and abroad; but, owing to the elevation of the Echinoderms to the rank of a subkingdom, the groups which he considered as families are now regarded as classes or orders. There is some doubt, however, as to whether the Blastoids and Cystids are in reality sufficiently distinct to rank as separate classes, for a large number of apparently intermediate forms have been discovered during the thirty years since Roemer wrote. The fundamental differences between *Pentremites* and *Echinosphærites* stand out even more clearly now than they did in 1850; but, on the other hand, it is difficult to assign a definite position to *Hybocystites* and to some other types of which Roemer knew nothing.

A short time before the appearance of Roemer's Monograph, Owen and Shumard [3] published descriptions of four new species of *Pentremites* from the Carboniferous Limestone of Iowa, U.S. One of these was founded upon an internal cast, as to the generic position of which there must naturally be a good deal of doubt, but the other three are now recognized as representing different genera, viz. *Granatocrinus*, *Cryptoblastus*, and *Orophocrinus*.

In the year 1854 was published the classical memoir of De Koninck and Le Hon [4] upon the Carboniferous Crinoids of Belgium, among which they included five so-called *Pentremites*. Three of these are now ranked with *Orophocrinus* and another with

[1] Journ. Acad. Nat. Sci. Philad. 1825, vol. iv. pt. 2, p. 292.

[2] Ueber die Morphologie und die Verwandtschafts-Verhältnisse der wirbellosen Thiere. Braunschweig, 1848, p. 42.

[3] Journ. Acad. Nat. Sci. Philad. 1850, vol. ii. pt. 1, p. 64. Reproduced, with additions, as "Descriptions of one new Genus and twenty-two new Species of Crinoidea from the Subcarboniferous Limestone of Iowa," Report Geol. Survey Wisconsin, Iowa, and Minnesota, 1852, pp. 587–598.

[4] "Recherches sur les Crinoïdes du Terrain Carbonifère de la Belgique." Mém. Acad. Roy. Belgique, 1854, Mém. 3, pp. 189–204.

Phænoschisma, while the last, *Pentremites crenulatus*, Roemer, is the type of *Mesoblastus*, one of our latest genera. Four more species were described in 1855 by Shumard[1], who was the first American author to use Roemer's nomenclature; while at the same time he brought forward some important new evidence respecting the closure of the summit-openings by additional plates, and three years later he published some further observations upon the same subject[2].

The year 1856 witnessed the establishment by Shumard and Yandell[3] of another new genus, *Eleutherocrinus*, for a very remarkable asymmetrical Blastoid from Kentucky; and during the next few years a great number of new species of *Pentremites* were described by Hall, Lyon, Shumard, Meek and Worthen, and others.

Some important descriptions of *Elæacrinus* and *Eleutherocrinus* were published in 1862 by Prof. J. Hall[4], who also proposed to use Troost's MS. name *Granatocrinus* for species of the type of *Pentremites Norwoodi*, Owen and Shumard.

During the next year some valuable observations on the closure of the summit and ambulacra were published by Dr. C. A. White[5], who also revived Say's theory respecting the presence of tentacles on the ambulacra, although Roemer had pointed out the difficulties involved in this view.

The year 1864 witnessed Von Seebach's proposal to make *Pentremites stelliformis*, Owen and Shumard, the type of a new genus, *Orophocrinus*[6]; and in the following year were published the most important observations of Rofe[7] on the structure of the hydrospires or subambulacral lamellar tubes in the British species of *Granatocrinus* and *Codaster*, with his suggestion that they probably served a respiratory function. About this time also Shumard[8] proposed to separate *Pentremites Reinwardti* and its allies under the generic name *Troostocrinus*.

[1] "Palæontology" in Swallow's First and Second Annual Report, Geol. Survey Missouri, 1855, pp. 185–187.

[2] "Descriptions of new Species of Blastoidea from the Palæozoic Rocks of the Western States, with some Observations on the Structure of the Summit of the genus *Pentremites*." Trans. St. Louis Acad. Sci. 1858, vol. i. pt. 2, pp. 238–248, pl. 9.

[3] "Notice of a new Fossil Genus belonging to the Family Blastoidea, from the Devonian Strata near Louisville, Kentucky." Proc. Acad. Nat. Sci. Philad. 1856, pp. 73–75, pl. ii.

[4] Fifteenth Annual Report, New York State Cabinet of Natural History (Albany, 1862), pp. 144–153.

[5] "Observations on the Summit-Structure of *Pentremites*, the Structure and Arrangement of certain parts of Crinoids, and Descriptions of New Species from the Carboniferous Rocks at Burlington, Iowa." Boston Journ. Nat. Hist. 1863, vol. vii. no. 4, pp. 481–489.

[6] "Ueber *Orophocrinus*, ein neues Crinoideengeschlecht aus der Abtheilung der Blastoideen." Nachr. kgl. Gesellsch. Wissensch. zu Göttingen, 1864, pp. 110, 111.

[7] "Notes on some Echinodermata from the Mountain Limestone," &c. Geol. Mag. 1865, vol. ii. pp. 248–251, pl. viii.

[8] "A Catalogue of the Palæozoic Fossils of North America.—Part I. Palæozoic Echinodermata." Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 384, note.

Several species of *Pentremites* (or rather *Pentremitidea*) from the Eifel were described by Schultze [1] in 1866; and *Granatocrinus* was formally adopted by Meek and Worthen [2] in the same year. Two years later they suggested the name *Tricœlocrinus* for a remarkable type allied to *Troostocrinus* [3]; and in 1869 they proposed to establish a new genus, *Codonites* [4], for the *Pentremites stelliformis*, Ow. & Shum., which (though unknown to them) had already been taken by Von Seebach as the type of *Orophocrinus.* They also confirmed White's observations respecting the closure of the summit-openings by additional plates, which likewise extend down the ambulacra so as to cover them in and convert them into tunnels. In this year, too, Billings [5] began the publication of a very striking series of papers on the structure of Crinoids, Cystids, and Blastoids, in which he devoted a good deal of attention to the morphology of *Pentremites*, *Codaster*, and *Elæacrinus.* The remarkable lamellar tubes beneath and between the ambulacra, which appear to have served the function of respiration, were designated by him as "hydrospires," and the summit-openings in connection with them were called "spiracles," names which have since been generally adopted.

In 1873 several excellent figures of Blastoids were published by Meek and Worthen [6]; but they were unfortunately not accompanied by any connected description of the morphological details which they illustrated so well.

Three years later an attempt was made by Mr. R. Etheridge, Jun.,[7] to elucidate the structure of Austin's little-known genus *Astrocrinites* on the basis of a new species discovered in the Scotch Carboniferous shales; and he subsequently described, under the general name *Pentremites* [8], an imperfectly-preserved fossil from the same horizon, which has since proved to belong to *Phænoschisma.* Many important observations on Blastoid morphology were published incidentally by Wachsmuth in his "Notes on

[1] "Monographie der Echinodermen des Eiflerkalkes." Denkschr. k. Akad. Wiss. Wien, Bd. xxvi. 1866, pp. 111–114.

[2] "Contributions to the Palæontology of Illinois and other Western States." Proc. Acad. Nat. Sci. Philad. 1866, p. 257.

[3] "Remarks on some types of Carboniferous Crinoidea, with Descriptions of new Genera and Species of the same and of one Echinoid." *Ibid.* 1868, p. 356.

[4] "Remarks on the Blastoidea, with Descriptions of New Species." *Ibid.* 1869, pp. 83–91.

[5] "Notes on the Structure of the Crinoidea, Cystidea, and Blastoidea." American Journ. Sci. vol. xlviii. 1869, pp. 69–83; vol. xlix. 1870, pp. 51–58; vol. l. 1870, pp. 225–240; Ann. & Mag. Nat. Hist. 1870, vol. v. pp. 251–266 and 409–416; vol. vii. 1871, pp. 142–158.

[6] Report, Geological Survey of Illinois, 1873, vol. v. pls. viii., ix.

[7] "On the Occurrence of the Genus *Astrocrinites* (Austin) in the Lower Carboniferous Limestone Series of Scotland, with the description of a new species (*A. Benniei*) and remarks on the Genus." Quart. Journ. Geol. Soc. 1876, vol. xxxii. pp. 103–115, pls. xii., xiii.

[8] "On the Occurrence of the Genus *Pentremites* (Say) in the Carboniferous Limestone Series of the East of Scotland; and Notes on Carboniferous Brachiopoda." Proc. Nat. Hist. Soc. Glasgow, 1881, vol. iv. pp. 260–263, pl. v.

the Internal and External Structure of Palæozoic Crinoids"[1]; and also by Messrs. Wachsmuth and Springer in the first two portions of their "Revision of the Palæocrinoidea."[2] In the year 1881 Montgomery[3] published an account of a new *Elæacrinus* from Canada; and several new American *Pentremites* were described by Hambach[4], who also published some valuable observations on the structure of the ambulacra. But at the same time he revived Say's and White's theory of the passage of tentacles through the pores of the ambulacra; and he not only totally denied the existence of summit-plates closing the mouth and spiracles, but also asserted that the supposed plates were merely Bryozoa or ovulum-like bodies. These statements were criticised by Dr. P. H. Carpenter[5]; and in the following year (1882) we commenced the publication of our joint views respecting the structure and classification of the group[6]. Roemer's terminology was revised and extended, while we proposed two new genera, *Phænoschisma* and *Schizoblastus*, in accordance with the previous suggestions of Billings and of Meek and Worthen respectively. At the same time, *Pentremitidea*, *Troostocrinus*, and *Orophocrinus* were adopted and more closely defined. In the next year we published a second series of notes[7], in which the genus *Acentrotremites* was proposed for the *Mitra elliptica* of Cumberland; and various points were noted in the structure of *Elæacrinus*, *Stephanocrinus*, *Tricœlocrinus*, and *Astrocrinus*. Certain new species of extra-British Blastoids were described in both these papers, while the geological and geographical distribution of the genera were set forth for the first time.

Our nomenclature and revision of the genera were accepted by Mr. Wachsmuth[8], who published in 1883 some important observations upon the basal plates, and proposed the new genus *Heteroschisma* for some new American species allied to *Codaster*; while new species of *Elæacrinus* and *Pentremitidea* were described by Barris[9]. The

[1] Amer. Journ. Sci. 1877, vol. xiv. pp. 115–127, and 181–191.

[2] Part I., Proc. Acad. Nat. Sci. Philad. 1879 [1880], pt. 3, pp. 226–378, pls. xv.–xvii.; Part II., *Ibid.* 1881 [1881–82], pts. 2, 3, pp. 177–411, pls. xvii.–xix.

[3] "A Blastoid found in the Devonian Rocks of Ontario." Canad. Nat. 1881, vol. x. pp. 80–84.

[4] "Contribution to the Anatomy of the Genus *Pentremites*, with description of new Species." Trans. St. Louis Acad. Sci. 1880, vol. iv. no. 1, pp. 145–160, pls. A, B.

[5] "On certain Points in the Morphology of the Blastoidea." Ann. & Mag. Nat. Hist. 1881, vol. viii. pp. 418–424.

[6] *Ibid.* 1882, vol. ix. pp. 213–252.

[7] "Further Remarks on the Morphology of the Blastoidea, with Descriptions of a new British Carboniferous Genus and some new Devonian Species from Spain." *Ibid.* 1883, vol. xi. pp. 225–246.

[8] "On a new Genus and Species of Blastoids, with Observations upon the Structure of the Basal Plates in *Codaster* and *Pentremites*." Report Geol. Survey Illinois, 1883, vol. vii. pp. 346–357. Revised in the Proc. Davenport Acad. Nat. Sci. 1885, vol. iv. pp. 76–87.

[9] "Description of some new Blastoids from the Hamilton Group." Report Geol. Survey Illinois, 1883, vol. vii. pp. 357–364. Revised in the Proc. Davenport Acad. Nat. Sci. 1885, vol. iv. pp. 88–94.

next year witnessed the production of another paper by Hambach [1], who reiterated his previous assertions respecting the presence of tentacles on the ambulacra, and the absence of summit-plates. At the same time he endeavoured to show the arbitrary nature of the classification which we had proposed for the different generic types hitherto referred to *Pentremites*; though he concluded by evolving a classification of the so-called *Pentremites*, which was based upon almost the same principles as our own, and was therefore, to a large extent, identical with it. But he refused to recognize any genera but *Granatocrinus* and *Orophocrinus* out of the six which have been removed from the old genus *Pentremites* by various authors, including his co-workers in America. A preliminary criticism of Hambach's views by Dr. P. H. Carpenter [2] is the latest addition to the literature of the Blastoidea up to the autumn of 1885 [3].

[1] "Notes about the Structure and Classification of the Pentremites." Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, pp. 537–547.

[2] "Further Remarks upon the Morphology of the Blastoidea." Ann. & Mag. Nat. Hist. 1885, vol. xv. pp. 277–300.

[3] A complete Bibliography of the Blastoidea will be found at the end of the Catalogue.

CHAPTER II.

THE STEM AND CALYX.

A. The Stem.

The stem of the Blastoidea is comparatively but little known, since individuals in which the stem remains attached to the calyx are but rarely found preserved. Mr. Wachsmuth informs us that he has a slab of *Pentremites* from the Chester Limestone in which three specimens have stems of between 5 and 8 inches in length; but we have seen nothing of this kind in any pieces of the Carboniferous Limestone from Bolland and Clitheroe, which are sometimes crowded with stemless cups of *Granatocrinus ellipticus.*

The best preserved stem which we have been able to examine is in a specimen of *Granatocrinus Norwoodi* belonging to Mr. Wachsmuth, which is figured in Pl. III. fig. 16. It consists of small, thin, discoidal joints, which have no special distinctive marks. Isolated stem-joints are abundant in every rock which contains Blastoid remains, but there is no test by which the stem-joints of a Blastoid can be distinguished from those of a Crinoid. No stem has yet been discovered which bears whorls of cirri as in the Pentacrinidæ and in some Palæozoic Crinoids (*Hystricrinus* and *Belemnocrinus*); but Mr. Wachsmuth informs us that he has obtained one *Pentremites* from the Kaskaskia Limestone in which the stem ends below in a branching root like that of the Bourgueticrinidæ. Both in this Pentremite and in *Granatocrinus Norwoodi* the stem consists of very numerous discoidal joints, but in *Granatocrinus Derbiensis* it appears to have been composed of more elongated joints, like those of the *Rhizocrinus*- and *Bathycrinus*-stems (Pl. VI. fig. 23).

In the British species of *Granatocrinus* the stem-facet is of moderate size compared to the diameter of the flat basal disc of which it occupies the centre (Pl. VIII. figs. 13, 18; Pl. IX. figs. 3, 4, 9, 13); while in *Orophocrinus*, *Phænoschisma*, *Cryptoschisma*, *Troostocrinus*, and other types with a more or less elongated basal cup, its narrow lower end rests directly upon the first stem-joint, which is sometimes preserved, as in *Phænoschisma Archiaci* and *Orophocrinus stelliformis* (Pl. XII. fig. 10; Pl. XVI. fig. 7).

Three genera of Blastoids—*Pentephyllum* (Pl. XVI. fig. 16), *Eleutherocrinus* (Fig. II. on p. 14), and *Astrocrinus* (Pl. XX.)—appear to have had no stem in the adult state, whatever may have been the case during early life. The asymmetry of

the basals in the two latter forms is so great that it is difficult to see where the stem could have been attached; while in good specimens of *Astrocrinus* the dorsal surface is uniformly covered with the minute tooth-like tubercles which seem to have borne spines, and there is no sign of any facet, even the sutures of the basals being hard to distinguish (Pl. XX. figs. 10, 13). It is, of course, quite possible that this may be a secondary condition comparable to that of the adult *Edriocrinus*, *Agassizocrinus*, and perhaps of *Marsupites* also. Whatever be the case in the latter type, the gradual disappearance of the stem-facet and closure of the cup below has been clearly traced in the two Palæozoic genera; and a somewhat similar transformation takes place in the centro-dorsals of many recent Comatulæ. The central opening on the dorsal surface is gradually closed up, and the cirrus-sockets obliterated by secondary deposits of limestone, so that the adult *Comatula* shows no trace whatever of ever having been attached to a stem. It is just possible that something of this kind may have taken place in *Eleutherocrinus* and *Astrocrinus*; but the two genera are so rare, that the discovery of transitional stages such as are known for *Edriocrinus* and *Agassizocrinus* is likely to progress but slowly.

B. The Calyx.

Excluding the summit-plates and the various structures which go to form the ambulacra, we may regard the calyx of all Blastoids as composed of three sets of plates, which correspond respectively to the basals, radials, and the primary or calyx-interradials of a Crinoid, more especially of such a form as *Cyathocrinus*. The interradial plates in the Blastoid calyx, to which Roemer gave the name of deltoids, correspond to the plates which were described by Wachsmuth and Springer and by Zittel as the orals of *Cyathocrinus*, since they were believed by these writers, and also by ourselves, to represent the oral plates of the Neocrinoidea. The position of the ambulacra upon the united edges of these interradial plates of *Cyathocrinus* and the Blastoids always seemed to us to be a difficulty in the way of regarding them as orals, as was first done by Wachsmuth and Springer and by Zittel, though we afterwards adopted their views. Mr. Wachsmuth [1], however, subsequently come to the conclusion, in which we entirely agree, that this homology is not a valid one, and that the so-called orals of *Cyathocrinus* and the deltoids of the Blastoidea are really true calyx-interradials like those of *Platycrinus*, *Rhodocrinus*, and a few Neocrinoids (*Guettardicrinus* and *Thaumatocrinus*). We shall therefore speak of them by Roemer's name "deltoids," postponing to a later chapter the discussion of the question what plates (if any) in a Blastoid do correspond to the orals of Neocrinoids.

Regarding the calyx as a whole, we would first notice two points concerning it, viz. its shape and the relative proportions of its component plates. In several species of *Granatocrinus*, *Mesoblastus*, and *Pentremites* the general outline of the calyx is somewhat in the shape of a bell, with the ambulacra extending downwards from the

[1] Proc. Davenport Acad. Nat. Sci. 1885, vol. iv. p. 77, note.

summit so as almost or quite to reach the broad flattened base (Pl. II. figs. 1–3, 14–17, 32–35 ; Pl. III. fig. 4 ; Pl. VIII. figs. 1, 14, 16, 19 ; Pl. IX. figs. 1, 2). In other species again the form is more or less globular (Pl. IX. figs. 6, 11, 12); ovoidal, as in *Heteroblastus* (Pl. VI. fig. 1), *Elæacrinus* (Pl. II. figs. 43, 46 ; Pl. XVIII. fig. 19), and *Eleutherocrinus* (Pl. XIX. figs. 4, 5), or even much elongated. But in all cases alike the ambulacra extend from one end of the calyx to the other, their proximal ends lying along the sutures of two deltoid plates, while their distal ends are received into the more or less deeply incised radials which surround the circle of small and somewhat flattened basals (Pl. VIII. figs. 3, 8, 13, 18 ; Pl. IX. figs. 3, 4, 9, 13). But in a large number of Pentremites, of which *P. pyriformis* is a good type (Pl. II. figs. 24–30), the basals are prolonged into a conical cup, and the radials are much less deeply incised to receive the ambulacra, so that the latter do not nearly extend along the whole length of the calyx. This is the case in the genera *Codaster*, *Orophocrinus*, *Phænoschisma*, *Cryptoschisma*, *Pentremitidea*, *Troostocrinus*, and others (Pl. IV. figs. 9, 11, 18 ; Pl. V. figs. 1, 3, 6, 9, 17, 20, 21, 25, 26 ; Pl. XII. figs. 2, 3, 5, 6, 10, 11 ; Pl. XIV. figs. 1, 4, 8, 10, 13, 14, 17 ; Pl. XV. figs. 1, 3, 6, 9 ; Pl. XIX. fig. 13). In types such as these the basals and the bodies of the radials form a cup which expands gradually from below upwards till it reaches its greatest diameter between the lips of the radials, in which the ambulacra terminate ; while their limbs and the deltoid pieces together make up a more or less flattened dome, in the centre of which the mouth is placed. In some species of *Orophocrinus* and *Pentremitidea* this dome is almost hemispherical in outline (Pl. IV. figs. 13, 18 ; Pl. XV. figs. 1, 3, 6) ; while in other types it has the form of a truncated cone (Pl. V. figs. 3, 17, 21 ; Pl. XII. fig. 11 ; Pl. XIX. fig. 13). In *Cryptoschisma Schulzi* and in *Codaster trilobatus* this disappears altogether, and the ventral surface is nearly flat (Pl. V. fig. 26 ; Pl. XIII. figs. 3, 10, 12, 15) ; while in *Stephanocrinus*, although the ambulacra occupy a nearly horizontal position, the interradial areas of the summit are produced into five prominent angular processes (Pl. XIX. figs. 11, 12).

Except in the Astrocrinidæ (Pl. XX.) the general outline of the calyx, as seen from above, is usually circular or pentagonal (Pl. IV. figs. 1, 14 ; Pl. V. figs. 7, 10, 13 ; Pl. VI. figs. 2, 8, 16 ; Pl. VIII. figs. 4, 9, 12 ; Pl. IX. fig. 8 ; Pl. XII. figs. 1, 4). In some species of *Pentremitidea*, however, there are more or less distinct reentering angles between the ambulacra (Pl. IV. figs. 8, 10, 12 ; Pl. V. figs. 2, 4, 16, 23), a character which culminates in *Orophocrinus stelliformis* (Pl. XV. fig. 11). *Eleutherocrinus*, although exhibiting a striking asymmetry in the character of its ambulacra, has a tolerably regular ovoidal outline in horizontal section (Pl. XIX. fig. 6) ; but in the allied genus *Astrocrinus* the want of symmetry extends into the rays, and the outline is that of a more or less regularly four-pointed star, one ray of which is often longer than the rest (Pl. XX. figs. 1, 7–14).

The composition of the calyx varies very considerably among the different genera

of Blastoids. The basals are quite small in *Granatocrinus* (Pl. VIII. figs. 13, 18; Pl. IX. figs. 3, 4, 9, 13), *Mesoblastus* (Pl. VI. figs. 9, 14; Pl. VIII. figs. 3, 8), *Acentrotremites* (Pl. XIII. fig. 17), and *Schizoblastus* (Pl. VI. fig. 17). But they form a more or less elongated cup in *Pentremites pyriformis* and its allies (Pl. II. figs. 24–30), *Troostocrinus* (Pl. V. figs. 21, 22; Pl. XII. fig. 11), *Pentremitidea* (Pl. IV. figs. 9, 11, 13, 16, 18), *Phænoschisma* (Pl. XI. figs. 5, 6; Pl. XII. fig. 10), *Codaster* (Pl. XII. figs. 2, 3, 5, 6; Pl. XIII. figs. 10, 12, 15), and *Orophocrinus* (Pl. XV. figs. 1, 3, 6, 9). They probably reach their maximum length relatively to that of the calyx in *Cryptoschisma Schulzi* (Pl. V. figs. 25, 26). On the other hand, the deltoids of this genus are scarcely visible externally. In the original of Pl. XIII. fig. 20 they are confined to the summit; but in the specimen represented in Pl. V. fig. 24 one of them is just visible at the top of an interradius. As this figure shows, however, they take a large share in the formation of the radial sinus, and the same is the case in *Codaster* and *Phænoschisma*, in neither of which genera are they properly visible at the sides of the calyx (Pl. X. figs. 18–20; Pl. XI. figs. 1, 2, 3, 5, 6; Pl. XII. figs. 1-6, 10; Pl. XIII. figs. 3, 9–12; Pl. XIV. figs. 1–5, 8–12). The same is the case in *Troostocrinus* and *Pentremitidea*, which have still more reduced deltoids, owing to the constriction of radial sinuses (Pl. V. figs. 1–11, 15–21). But they seem to be relatively large and visible externally in Hall's *Pentremites leda*, which we are inclined to refer to *Pentremitidea* on account of its other characters (Pl. V. figs. 12, 13).

On the other hand the deltoids are relatively very large in *Schizoblastus Sayi* and in *S. Rofei* (Pl. III. figs. 1–3; Pl. VIII. fig. 9), and in *Granatocrinus Derbiensis* (Pl. IX. figs. 1, 2, 6), the radials being very greatly reduced and only enclosing quite small portions of the tips of the ambulacra (Pl. IX. figs. 3, 4). This condition reaches its maximum in *Elæacrinus*, which has quite small basals, so that the whole of the calyx, with the exception of the very limited dorsal surface, is formed by the interradials (Pl. II. figs. 45 & 46). This genus is further distinguished by the presence of an anal plate which divides the posterior deltoid into two parts (Pl. XVIII. fig. 19).

C. The Basals.

The genus *Pentremites* was described by Say[1] as having a pelvis of three unequal pieces, two being pentagonal and one quadrate (Pl. V. fig. 29). Goldfuss[2], however, was led to believe that *Pentremites* had five basals like most Crinoids; but this error was pointed out by Roemer[3], who confirmed Say's description and illustrated it by a good figure. This tripartite division of the base of the Blastoids has never been further disputed; but it is a different division from that which presents itself in

[1] Journ. Acad. Nat. Sci. Philad. 1825, vol. iv. pt. 2, p. 292.

[2] Petrefacta Germaniæ, Th. i. 1826, p. 160.

[3] Archiv f. Naturgesch., 1851, Jahrg. xvii. Bd. i. pp. 326–329.

Platycrinus, though in both cases the base is monocyclic, tripartite, and symmetrical, as was pointed out by Beyrich[1]. The antero-posterior axis which passes through the anus and the opposite or anterior ray is called by him the radial axis, while that which divides the base symmetrically is known as the dorsal axis. The accompanying diagrams show that, while the dorsal axis of *Platycrinus* passes along the left postero-lateral ray, that of the Blastoid passes along the right postero-lateral ray (Fig. I.). It remains to be seen how far this rule holds good in the two remarkably asymmetrical types *Eleutherocrinus* and *Astrocrinus*, which will be best considered later. But so far as the regular Blastoids are concerned, we know of no genus which does not conform to it, though individual exceptions may occur, as will be explained subsequently.

It will probably conduce to clearness and brevity if we follow the plan which was first introduced by Professor Lovén, and has since been very generally adopted by Echinoderm students, and employ a special designation for each of the rays in the

Fig. I.

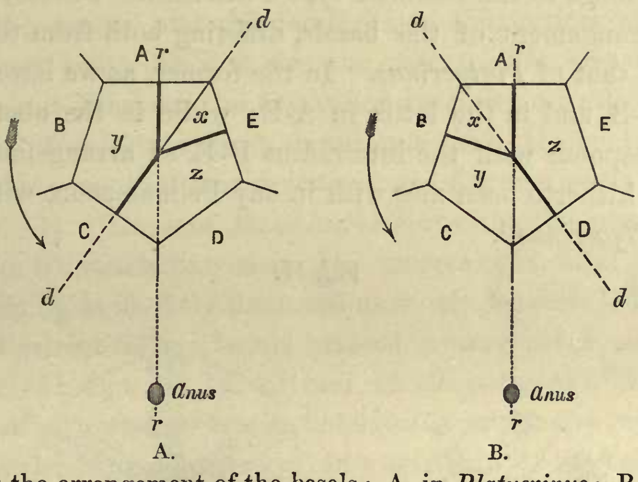


Diagram showing the arrangement of the basals: A, in *Platycrinus*; B, in the Blastoids.

A, B, C, D, E. The five radii of the calyx. *x*. The small azygos basal. *y*, *z*. The two larger basals. *d* . . . *d*. The dorsal axis. *r* . . . *r*. The radial axis, in which the anus is situated.

The arrows show the (probable) direction of the spirally coiled digestive tube.

organization of a Blastoid. It has been proposed by one of us[2] to denote each of the five ambulacra of a Crinoid by the letters A to E. When an endocyclic Crinoid, such as *Pentacrinus*, is placed with its ventral surface upwards and the anal interradius nearest to the observer, the opposite ray may be called the anterior one. Let

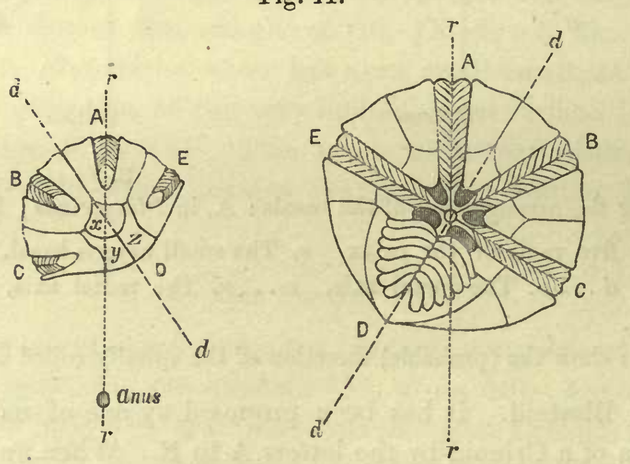
[1] "Ueber die Basis der Crinoidea brachiata." Monatsber. k. preuss. Akad. Wiss. Berlin, 1871, pp. 42, 51.

[2] 'On the genus *Actinometra*, Müll., with a Morphological Account of a New Species from the Philippine Islands.' Trans. Linn. Soc., Zool. 1879, vol. ii. p. 26.

us denote this by the letter A, and call the others B, C, D, E respectively, following the hand of a watch or the spiral twist of the coiled intestine. B and C are therefore the rays of the left or east side of the disk, while D and E are on the right or west; so that the anal interradius is between C and D. Viewed from the dorsal side these positions are of course reversed, and the rays B, C, D, E follow one another against the watch-hand. If the same rule be applied to the Blastoids (Fig. I., B), we find that the small basal lies in the left anterior interradius between the rays A and B; while the suture between the two large basals coincides with the right posterior radius or D. Let us call the small basal *x*, and the other two *y* and *z* respectively, *y* lying under ray C, and *z* under E, as shown in the accompanying diagram (Fig. I., B). Comparing the Blastoid with *Platycrinus*, we may then express the difference between the two types by saying that in the former the basal *x* is in the interradius A-B, while in the latter it is in A-E (Fig. I., A).

Among the many species of *Platycrinus* exceptions will doubtless be found to this rule, but so far as the Blastoids are concerned we have only met with one aberrant individual. It belongs to the common type *Pentremites Godoni*, and represents an altogether new arrangement of the basals, differing both from that of the ordinary Blastoid and from that of *Platycrinus*. In the former, as we have just seen, *x* lies in the interradius A-B, and in the latter in A-E; while in the aberrant individual of *P. Godoni*, *x* corresponds with the interradius D-E, an arrangement which, so far as we know, has not hitherto been met with in any Pelmatozoon, with the exception of the recent genus *Hyocrinus* [1].

Fig. II.



A. B.

Diagrams to show the relations of the dorsal and ventral axes in *Eleutherocrinus Cassedayi* (adapted from Shumard and Yandell).

The lettering as in Fig. I. A, dorsal, and B, ventral aspect.

With the above facts before us, we may now endeavour to determine the position of the radial axis in the asymmetrical Astrocrinidæ. Taking *Eleutherocrinus* as the

[1] Zool. Chall. Exp. part xxxii. 1884, p. 223.

type, we find that the azygos basal is relatively small, and occupies a nearly central position at the dorsal pole; while the other two are of considerable length and extend upwards on to the side of the calyx beneath the azygos ray (Fig. II., A). If, as, in other Blastoids, the suture between the paired basals (*y*, *z*) correspond to ray D, then this must be the designation of the broad abnormal ambulacrum, and the spiracle to its left must be regarded as the anal spiracle (Fig. II., B). Like its fellow on the right of this ambulacrum (between D and E) it is described by Shumard and Yandell[1] as having no median septum such as occurs in the three spiracles at the sides of the anterior ambulacra. But we know too little about this remarkable type, and still less about *Astrocrinus*, to be able to say much about the structure of the ventral side.

The extent to which the basals are developed varies very greatly among different Blastoids. In *Granatocrinus campanulatus* they form a five-pointed star which occupies the centre of the flat under-surface formed by the pentagon of radials (Pl. VIII. fig. 13). In the other British species of *Granatocrinus* (Pl. IX. figs, 3, 4, 13), and more especially in *G. ellipticus* (Pl. VIII. fig. 18), this surface is somewhat hollowed out in the centre, and the basals lie at the bottom of the concavity, as seen from the dorsal side. This is also the case in *Elæacrinus* (Pl. II. fig. 45); while in *Granatocrinus Norwoodi* the excavation reaches a considerable relative depth and encloses some of the uppermost stem-joints (Pl. III. fig. 16). The basals of *Schizoblastus* are also somewhat inconspicuous, and flat or slightly concave in general aspect (Pl. VI. fig. 17). Those of *Mesoblastus* may either be concave as in *M. angulatus* (Pl. VIII. fig. 8), nearly flat as in *M. elongatus* (Pl. VIII. fig. 3) and *M. crenulatus* (Pl. VI. fig. 9), or slightly produced as in *M. Sowerbii* (Pl. VI. figs. 12, 14).

In the genus *Pentremites* the basals present a very great amount of variation. In *P. conoideus* (Pl. II. figs. 16, 18, 20) and *P. elongatus* (Pl. II. figs. 14, 15) they are almost as flat as in *Granatocrinus campanulatus*, or at any rate but very slightly convex, so that they scarcely appear at all in a side view of the calyx (Pl. II. figs. 16, 18, 20; Pl. III. fig. 4). Those of *P. Godoni* are sometimes more conspicuous and just visible in a side view (Pl. II. figs. 1–7); and all gradations are traceable between this condition and that of the typical *P. pyriformis*, in which the basals form a well-defined cup, the interradial angles of which may reach to more than one third the distance between the dorsal and ventral poles (Pl. II. figs. 24–30). All the species of *Pentremitidea* have relatively high basals, as is well seen in Plates IV. and V.; and they are unusually high in the only known species of *Cryptoschisma* (*C. Schulzi*). In some individuals of this type they reach a very great length (Pl. V. fig. 25), and may take up two thirds of the entire height of the calyx, as is well shown in Roemer's figure[2]. In this respect the basals resemble those of many species of *Rhizocrinus*,

[1] Proc. Acad. Nat. Sci. Philad. 1856, vol. viii. p. 74.

[2] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. Taf. iv. fig. 18*a*.

such as the Tertiary *R. Thorenti* and the recent *R. Rawsoni*; and there is a further similarity between the two types, for the long basal cup is not unfrequently marked by one or more circular constrictions, which are sometimes so distinct as to have been taken for sutures both in the Blastoid and in *Rhizocrinus* (Pl. V. figs. 25, 26).

The basals of *Phænoschisma* resemble those of *Pentremitidea* (Pl. V.), being lowest in *P. caryophyllatum* (Pl. XIV. figs. 1, 4), and highest in *P. Archiaci* (Pl. XII. fig. 10). Those of *Orophocrinus* (Pl. XIV. fig. 17; Pl. XV. fig. 1; Pl. XVI. figs. 5, 7, 8) are also relatively high, except perhaps in *O. Puzos* (Pl. XIV. fig. 14). In all these four generic types, as also in *Pentremites pyriformis* (Pl. II. figs. 24–30) and its allied forms, the basal cup expands uniformly upwards from its lower to its upper edge. This is also true of some species of *Codaster* as *C. alternatus*, *C. pyramidatus*, and *C. Hindei* (Pl. XII. figs. 2, 3, 5). But in the British species (Pl. XIII. figs. 10, 12, 15) this is not the case. For a short distance above the articular facet the basal cup expands but little; but it soon opens out somewhat rapidly until it reaches the full diameter of the calyx, or nearly so.

In all these types, with the partial exception of *Codaster trilobatus* (Pl. XIII. figs. 2, 13), the general outline of the basal cup is that of a tolerably regular pentagon (Pl. IV. fig. 16; Pl. V. figs. 8, 11, 14, 29). But in *Troostocrinus*, *Tricœlocrinus* (Pl. XIX. fig. 14), and *Stephanocrinus* it is very distinctly triangular. The radials form a regular pentagon, the sides of which are interradial. But the side representing interradius A-B is not continued down on to the basal part of the cup; for the two ridges which bound it approach one another below and unite into the single ridge which marks the middle line of the azygos basal *x* (Pl. XIX. fig. 14). The next interradius B-C forms one side of the basal triangle; and another is compounded of the two interradii C-D and D-E, owing to the gradual obliteration of the ridge which separates their upper ends, while the third side of the triangle corresponds to the interradius E-A. The three angles of the trihedral base thus coincide with the median lines of the three basals, while its sides correspond to the interbasal sutures (Pl. XIX. fig. 14). In *Troostocrinus* and in *Stephanocrinus* the base narrows down to a triangular lower surface, in the centre of which is the circular facet for articulation with the stem. But in *Tricœlocrinus*, which has a relatively wider cup supported by lower and more spreading basals, the lines of the three sutures which correspond to the flat sides of the *Troostocrinus* base, are "so very profoundly and broadly excavated as to impart a very remarkable appearance to the lower part of the fossil."[1] A slight indication of this character also appears in some specimens of *Codaster trilobatus* (Pl. XIII. fig. 2).

The calyx of many Blastoids is marked by very well defined ridges which start from the bottom of the basal cup and extend upwards until they meet the radial lips

[1] Meek and Worthen, Report Geol. Survey Illinois, 1873, vol. v. p. 507.

at the distal ends of the ambulacra (Pl. IV. figs. 13, 16; Pl. V. figs. 6, 8, 14, 29; Pl. XII. figs. 2, 3; Pl. XV. fig. 6; Pl. XVI. fig. 16; Pl. XVIII. fig. 12; Pl. XIX. figs. 11–14). The general arrangement of these ridges is the same in all Blastoids, and is perhaps best studied in *Stephanocrinus*, in which type they are very strongly marked (Fig. III.).

Fig. III.

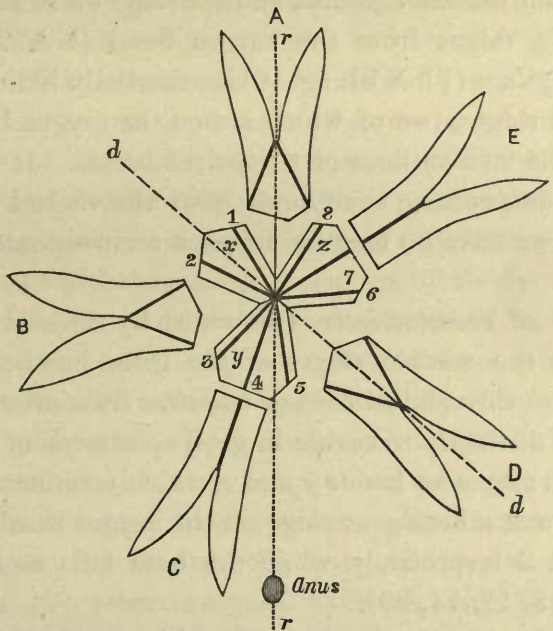


Diagram to show the positions of the ridges (1–8) on the basals and radials of *Stephanocrinus angulatus* (modified from Roemer).
The lettering as in Fig. I.

The small basal x is marked by two ridges (1 & 2) which rapidly diverge and terminate respectively in the lips of radials A and B. There are three ridges on basal y. The first (No. 3) passes on to radial B and meets at its lip the second ridge from basal x. The next (No. 4), which is much more prominent, passes directly upwards on to the middle line of radial C and ends in its lip; while the third (No. 5) terminates in the lip of radial D, where it meets a similar ridge (No. 6) from the next basal, z (Pl. XIX. figs. 11, 12). The median ridge of this basal (No. 7), also larger than its fellows, passes directly on to radial E; while the eighth and last ridge joins the first at the lip of radial A. Of these eight ridges four are stronger than the rest, viz. the median ones on each of the large basals (Nos. 4 & 7), and the two diverging ridges on the azygos basal (1 & 2).

The same is the case in *Tricœlocrinus*, as seen in Pl. XIX. fig. 14, which also shows very clearly how the trimerous symmetry of the basals passes into the pentamerous symmetry of the radials. In the first place, an additional side A–B is introduced by

the divergence of the two strong ridges (1 & 2) in the azygos basal x (which is placed downwards in the figure), as is well shown in the side view (Pl. XIX. fig. 13). This one angle of the trihedral base thus corresponds to radii A and B; while its other two angles send ridges (4 & 7) on to C and E. The D radius is formed opposite to the side joining these two angles by the convergence of the adjacent ridges (5 & 6), which start from these angles as described above. They are stronger than ridges 3 & 8, which start from the sâme points, and converge on to radials A and B, where they meet the strong ridges from the azygos basal (1 & 2). The base of the asymmetrical *Pentephyllum* (Pl. XVI. fig. 16) is essentially like that of *Tricœlocrinus*. It has four prominent ridges, two of which are on the azygos basal, while the other two (4 & 7) occupy the median lines of the paired basals. It might be possible to use this criterion for determining the symmetry of the ventral side, as in the case of *Eleutherocrinus*; but we have no material for such an investigation except an internal cast.

The trihedral base of *Troostocrinus* is bounded by ridges 4 & 7 and the common stem of 1 & 2, *i. e.* by the median ridges of the three basals, and the same is the case in the more or less three-lobed base of *Codaster trilobatus* (Pl. XIII. figs. 2, 13). This character is also distinctly traceable in good specimens of *Pentremites* and *Pentremitidea*, viz. median ridges on basals y and z, which terminate in the lips of radials C and E respectively, and a divergent ridge on the azygos basal x, the limbs of which end on radials A and B respectively, while the base falls away in the direction of radius D (Pl. V. figs. 8, 11, 14, 29).

The radially situated under-basals which occur in so many Crinoids, both Palæozoic and Neozoic, appear to be altogether unrepresented in the Blastoidea; though an attempt has been made to establish the existence of a series of plates intervening between the basals and the top stem-joint. Thus Lyon [1] wrote in 1857 that "*Pentremites florealis*, *globosus*, *pyriformis*, and others have severally three small plates or pieces, distinctly separated from the pieces heretofore designated as the "*Basal pieces*;" these three pieces form the base of the cup, and as they lie below the pieces heretofore recognized as basal, are true basal pieces, and the others necessarily become first radials." In consequence of this observation Lyon was led to propose a change in the generic formula of *Pentremites*. The three plates which he believed himself to have discovered were termed basals; while those which lie immediately above them, and had been previously regarded as the basals, received the name "first radials"; and the true first radials or fork-pieces were transferred to the category of second radials [2]. It never seems to have occurred to Lyon that there might be two

[1] Palæontological Report, Owen's 3rd Report Geol. Survey Kentucky, 1857, pp. 468, 469.

[2] This is an excellent instance of the traps which nature lays for those empirical palæontologists who neglect the study of morphology. No one who had mastered Müller's memoir on *Pentacrinus* (then fifteen years old) could possibly have made such a blunder.

series of basal pieces in *Pentremites*, as in *Poteriocrinus*. This assumption would have led him into error, but not into one of such a serious nature as he committed in describing *Pentremites* as having only three radial pieces, two large and one small, the latter, be it remembered, being strictly interradial in position. No notice seems to have been taken of Lyon's observations till 1869, when Billings published a confirmation of them [1]. He proposed to call the upper set of plates "subradials," retaining the name "radials" for the fork-pieces. Meek and Worthen [2] pointed out that the correspondence in position of the two rows of plates is an objection to homologizing them with the basals and subradials of Crinoids which alternate with one another. Regarding the plates of the upper row or subradials (Billings) as the true basals, they spoke of the lower series as the supplemental basals. Lyon had described them in *Codaster alternatus* as well as in *Pentremites*, and Meek and Worthen noted their presence in adult specimens of *Orophocrinus stelliformis*; while they went on to say that "although adult specimens of the type of the genus under consideration have these lower pieces so solid as we see them in the true *Pentremites*, *young individuals show clearly that they are actually composed of five or six of the upper joints of the column, enlarged and anchylosed together*." They believed that in one specimen of *O. stelliformis*, which formerly belonged to Mr. Wachsmuth, the uppermost part of the stem is divided by longitudinal sutures corresponding with the interbasal sutures, as is the case in *Barycrinus*. Wachsmuth [3] admits that "the longitudinal sutures are not shown distinctly, but probably do exist in the specimen." He objects, however, to the origin assigned by Meek and Worthen to the supplemental basals of *Orophocrinus*, on the ground that no transition forms have ever been found in this or in any allied species. But he goes on to say that he has sometimes noticed "a slight angular depression around the lower end of the cup. This depression, which has somewhat the appearance of a suture, is caused by the more rapid spreading of the upper portion of the basals. Such, at least, is the case in some species of *Codonites*, *Codaster*, and *Troostocrinus*, in which the base appears as if it might be dicyclic, but actually is monocyclic, and in which the lower part is almost cylindrical, and resembles an elongate columnar joint, while the upper part is conical."

In all the three types mentioned by Wachsmuth there is a more or less elongated base (Pl. XII. figs. 2, 3, 11; Pl. XIII. figs. 3, 10, 12, 15; Pl. XIV. fig. 17; Pl. XV. figs. 1, 3; Pl. XVI. figs. 5, 7); and we think that he is probably correct in explaining the occurrence of this furrow by the rapid increase in the width of the cup during the later stages of its growth. This is certainly the explanation of the apparently

[1] American Journ. Sci. 1869, vol. xlviii. p. 83, and 1870, vol. l. p. 226; Ann. & Mag. Nat. Hist. 1870, vol. v. p. 266, and 1871, vol. vii. p. 143.

[2] Report Geol. Survey Illinois, 1873, vol. v. p. 464.

[3] Proc. Davenport Acad. Nat. Sci. 1885, vol. iv. p. 79.

circular suture which is so often visible in *Cryptoschisma Schulzi* (Pl. V. figs. 25, 26). But his explanation does not altogether apply to the much flatter base of *Pentremites*, in which he himself says that additional modifications have taken place.

According to Hambach [1] the articulating surface in the centre of the base is often "surrounded by a triangular or clover-leaf-shaped furrow, which induced some authors to suppose that the base was composed of twice three pieces; but numerous examinations of isolated pelves have convinced me of the fact that this furrow is only superficial and not a separating suture" (Pl. V. fig. 27). With this statement we are quite in accordance, and we think that the question of supplemental basals in the Blastoidea is now finally settled. It remains, however, to try and discover the real nature of the structure which has been spoken of by this name. It is well described by Wachsmuth [2] in *Pentremites* as "a tripartite plate in form of a clover-leaf, occupying the central portion of the basal disc, into which it extends for some distance, following its curvature. It is frequently somewhat elevated above the general surface of the basals, and can be observed in most specimens with the naked eye. The sutures which separate the basals by their shorter sides, in the usual way, divide the lower leaves lengthwise." This last statement requires a slight modification. The basals are divided asymmetrically, two of them (*y*, *z*) being larger than the third; but the sutures on the articular facet at their lower extremity divide it into three equal parts, the angles at which the sutures meet being all equal (Pl. V. fig. 29). Figures have been published which illustrate this point; but we do not know that any explanation of it has yet been given. It results from a slight curvature in the two sutures at the sides of the small basal *x*, as they approach the dorsal pole. An indication of this is shown in Lyon's figure [3] of the base of *Pentremites angularis*, and we give similar figures which show its occurrence in *Pentremitidea Wachsmuthi* and in *Pentremites elongatus* (Pl. V. figs. 8, 29). The curvature of one of these sutures is also seen in the side views of *Pentremitidea similis* (Pl. X. fig. 2), *Orophocrinus stelliformis*, var. *campanulatus*, Hamb. (Pl. XVI. fig. 5), *Phænoschisma Archiaci* (Pl. XII. fig. 10), and *Cryptoschisma Schulzi*. In the latter type it commences just below the circular furrow, which causes the basals to appear as if they were pentagonal in form (Pl. V. fig. 25). We have seen the same peculiarity in *Codaster trilobatus*, and have no doubt of its occurrence in *Stephanocrinus*, *Troostocrinus*, and in *Tricœlocrinus*, though the condition of our specimens has prevented our ascertaining it for ourselves. In fact Meek and Worthen [4] figure the articular facet on the lower surface of the basal cup in *Tricœlocrinus* as symmetrically divided by the three radial sutures,

[1] Trans. St. Louis Acad. Sci. 1880, vol. iv. no. 1, pp. 146, 147.

[2] Proc. Davenport Acad. Nat. Sci. 1885, vol. iv. p. 81.

[3] "Descriptions of four new species of Blastoidea from the Subcarboniferous Rocks of Kentucky." Trans. St. Louis Acad. Sci. 1860, vol. i. no. 4, pl. 20. fig. 3 *a*.

[4] Report Geol. Survey Illinois, 1873, vol. v. pl. xvi. fig. 4 *a*.

though the curvature of these sutures before they reach the lower edges of the radials is not shown.

We are inclined to think that the alteration in the course of the interbasal sutures and the apparent presence of the so-called supplemental basals, are alike due to a secondary limestone deposit upon the upper part of the stem, which spreads over the lower portion of the cup, and is segmented in a slightly different manner from the parts which it encloses (Pl. V. fig. 25). One or two instances of secondary deposits of this nature have already been noticed among the Neocrinoids. Thus in a stem of the recent *Pentacrinus Naresianus* [1] several of the lower joints are covered by a sheath of limestone which almost obliterates the cirrus-sockets at the nodal joints; while the suture-lines between its component parts do not quite coincide with those between the stem-joints which it encloses. Then, again, on one side of a specimen of the fossil *Millericrinus Pratti* [2] two large stem-joints are visible just below the basals; but they are broken away on the other side, and it then becomes manifest that they enclose a central core of much thinner and narrower joints, which seem to extend upwards to the basals, and to have been continuous with those lower down the stem. There appears therefore to have been a secondary deposit of limestone outside the upper stem-joints, which divided up into segments not corresponding with those enclosed by it. In this case the interbasal sutures are not continued downwards on to the apparently large stem-joint beneath them. But in other respects the resemblance between this structure and the supposed supplemental basals of the Blastoids is a very striking one, and we are inclined to think that the presence of the latter is due to some secondary deposit of this kind. Another reason for thinking so is, that they are not unfrequently marked by more or less distinct circular lines which might be mistaken for the interarticular sutures of the stem (Pl. V. fig. 25).

It is, we think, this structure which is described by Wachsmuth [3] in the following passage. "In one of my specimens, which I take to be an extremely large specimen of *Pentremites Godoni*, I find within the clover-leaf another leaf-like structure, but of less width, and beneath it eight joints of the column, divided longitudinally in the same direction as the basals. The inner leaf is at its border as distinctly marked as the outer one; it extends not far beyond the column, but is considerably wider, and very much higher than the stem-joints, which are so extremely short that there are eight joints to a length of half a line. The structure is such that there can be but little doubt that the inner leaf, although differing considerably in its dimensions from the succeeding stem-joints, is actually nothing else but the proximal joint, which had become enlarged and gradually anchylosed with the basals. It is quite evident that the outer clover-leaf had a similar origin. At the outer leaf the sides of the anchy-

[1] Zool. Chall. Exp., Part xxxii. 1884, pp. 328, 329, pl. xxx. *a*, figs. 4, 5.

[2] Quart. Journ. Geol. Soc. 1882, vol. xxxviii. p. 33, pl. i. fig. 21.

[3] Proc. Davenport Acad. Nat. Sci. 1885, vol. iv. p. 81.

losed joint were more extended, and became almost entirely absorbed into the basal plates, leaving only external marks, while at the inner ones the column structure can yet be recognized, although the joint here has actually become a part of the basal plates." The regular distribution of the clover leaves along the depressed lines of the interbasal sutures which correspond to the great hollows in the base of *Tricœlocrinus* (Pl. XIX. fig. 14) is very marked, and is particularly well shown in one of our specimens of *Pentremitidea Paillettei*. The lower part of the basal cup is covered by a tolerably regular overgrowth, near the bottom of which a definite circular line is visible, just as in *Pentremites*; but three lancet-shaped processes extend upwards from this and occupy the hollows between the convexities of the basals. This overgrowth seems only to occur in those Blastoids which have relatively large and symmetrical basals, and not perhaps in all of these; for, as already remarked, we have no knowledge of it in *Troostocrinus*, *Tricœlocrinus*, and *Stephanocrinus*, nor in *Granatocrinus*, *Cryptoblastus*, *Schizoblastus*, and *Mesoblastus*, nor in the asymmetrical *Eleutherocrinus* and *Astrocrinus*. The tripartite division of the basals is, however, common to all Blastoids.

D. The Radials.

The fork-pieces or radials, which rest upon and alternate with the basals of a Blastoid, present a great amount of variation in their characters. Homologous with the radials of a Crinoid, and therefore also with the ocular plates of an Urchin, they differ altogether from the former in bearing no articulated arms, while they closely resemble the latter in their relation to the distal ends of the ambulacra, as is well shown in *Granatocrinus Derbiensis* (Pl. IX. fig. 4), and still more markedly in *Elæacrinus Verneuili* (Pl. II. fig. 45).

Several among the great variety of forms which are presented by the radials of the Blastoids correspond to similar types among the Crinoids. Thus, for example, the more or less spade-like radials of *Codaster trilobatus* (Plate XIII. fig. 3) closely resemble those of *Dichocrinus*, or of the recent *Hyocrinus*. In all three alike there is a somewhat well defined medio-dorsal convexity which becomes more prominent towards the ventral edge of the plate. But while in *Hyocrinus* this marks the articulating facet of an arm on to which the ambulacrum passes from the disc, the ambulacrum of *Codaster* has no brachial extensions but terminates in the radial lip. The ventral surface of the radial (Pl. XIII. figs. 1, 4) is also wider than that of the corresponding plate in *Hyocrinus*, which is little more than an edge for the support of the first brachials, and does not contribute in any way to form the roof of the visceral cavity. In the *Codaster*, however, the ventral surface of the radials is somewhat extended right and left of the ambulacrum, and supports the distal ends of the lamellar hydrospire-sacs which dip down some way into the visceral cavity (Pl. XIII. figs. 1, 4, 5–8). The general relation of the calyx of *Codaster* to its ambulacra finds a very

close parallel in *Cyathocrinus*; and the resemblance is further increased by the presence in both forms of the large rhomboidal interradial plates, which roof in the greater part of the visceral cavity, leaving only the mouth in the centre, and in *Codaster* support the proximal ends of the hydrospires.

In other species of *Codaster* the ventral edge of each radial is not so nearly horizontal as in *C. trilobatus*, but V-shaped with the point downwards; and the consequence is that the ventral surface is no longer flat or nearly so, but marked by five more or less depressed areas, the middle and lowest parts of which are occupied by the ambulacra (Pl. X. figs. 19, 20; Pl. XII. figs. 1–6). Each of these areas is known as a radial sinus. Its outer edge is formed by the two prongs of the V, which rise from the radial lip towards the ventral end of the interradial suture. From the point where these three lines meet a more or less well-defined crest extends towards the mouth and marks the middle line of each interradial plate, the boundaries of which descend the sloping sides of the radial sinuses till they meet the ambulacra (Pl. X. figs. 18, 19; Pl. XII. figs. 1, 4; Pl. XVI. fig. 1), just as the radio-deltoid sutures do on the flat top of *Codaster trilobatus* (Pl. XIII. figs. 1, 4, 8). The sides of the radial sinuses are thus formed partly by the ventral surface of the radials, and partly by the interradials. In the flat-topped *Codaster trilobatus*, the middle line of the interradial stands out rather prominently as a subprismatic, lanceolate ridge, somewhat above the general plane of the hydrospire-slits (Pl. XIII. figs. 1, 4, 6, 8–12). But in proportion as the radial sinus gets deeper and deeper, the ridges at its sides become sharper and sharper and appear less and less distinct in the general aspect of the summit (Pl. X. figs. 19, 20; Pl. XII. figs. 1–6). Since they all converge on the mouth they may be conveniently designated as the oral crests or oral ridges.

When we first proposed this name for the ridge on the middle line of the interradial or deltoid piece we, like Wachsmuth and Springer, regarded the latter as representing an oral plate of a Neocrinoid. Now, however, that this view has been abandoned, Wachsmuth [1] says, "It is self-evident that the oral ridge of Etheridge and Carpenter should be called the interradial ridge." This term, however, is equally applicable to any ridge occupying an interradial position on the exterior of the calyx, *e. g.* the medio-dorsal ridge of a basal; and we therefore think it inexpedient to limit its use in the sense suggested by Wachsmuth. "Oral ridge" has the double advantage of brevity and of clearly indicating that the actinal and not the abactinal surface is being described; while we do not see that it involves any question of the homology of the parts concerned.

When the upper edge of the radial becomes V-shaped, as in *Codaster alternatus*, var. *elongatus*, Wachsm., *C. pyramidatus*, and *C. Hindei* (Pl. X. fig. 20; Pl. XII. figs. 2, 5),

[1] Proc. Davenport Acad. Nat. Sci. 1885, vol. iv. p. 77, note.

its outer surface may be regarded as composed of two parts, namely—the body, which extends from the basiradial suture up to the radial lip, in which the ambulacra terminate; and the limbs, which reach upwards at the sides of the ambulacra until they meet the outer ends of the oral crests. The adjacent limbs of contiguous radials are thus produced upwards between the ambulacra, and the general aspect of the calyx depends upon their relative length and upon the convexity of their surface more than upon any other point in the character of the radials.

In *Codaster pyramidatus* and in *C. Hindei* the radial limbs are quite short, so that the sinus is wide and shallow; and the intervening oral crests slope downwards from the mouth, which is at a higher level than the interradial angles of the calyx (Pl. XII. figs. 2, 5). The spade-like radials of *Codaster trilobatus* cannot be said to have any limbs at all, and the term fork-pieces is hardly applicable to them (Pl. XIII. figs. 3, 9–12), while the mouth and oral crests are at much the same level. But in *C. alternatus*, var. *elongatus*, the radial limbs are longer, the sinuses deeper and more steep-sided, and the oral crests actually slope downwards towards the mouth (Pl. X. fig. 20). The same is the case in *Phænoschisma Verneuili* and *P. Archiaci* (Pl. XI. figs. 5, 6; Pl. XII. fig. 10; Pl. XIV. fig. 8); while in *P. nobile*, *P. caryophyllatum*, and *P. acutum* the mouth and oral crests are in nearly the same plane (Pl. XI. fig. 2; Pl. XIV. figs. 1, 10). The radials of these species and especially of *P. caryophyllatum* are very much incised; but the sinuses, though deep, are relatively wide and not completely filled by the ambulacra, so that parts of the hydrospire-clefts are still visible on their walls.

A parallel series of variations in the shape of the radials is presented by the genera *Cryptoschisma* and *Pentremitidea*, in which, as in *Phænoschisma* and *Codaster*, the deltoids are confined to the summit, not appearing at all on the exterior of the calyx. The radials of *Cryptoschisma Schulzi* are almost as spade-like as those of *Codaster trilobatus* (Pl. V. figs. 25, 26). But their ventral surface, on which the hydrospire-slits are situated, is concealed by the broad ambulacra (Pl. V. figs. 23, 24; Pl. XIII. fig. 20). Between these are the oral crests formed by the deltoid pieces very much as in *Phænoschisma acutum* (Pl. XIV. fig. 11). In *Pentremitidea Paillettei* (Pl. IV. fig. 9; Pl. XIV. fig. 13) and *P. Lusitanica* (Pl. IV. fig. 11; Pl. V. fig. 20) the radials are more distinctly convex and spread outwards above the basal cup, so that although there is a moderately long sinus it does not extend very far down towards the basiradial suture. On the other hand, in *Pentremitidea angulata* (Pl. IV. fig. 18), *P. Wachsmuthi* (Pl. V. fig. 6), *P. Gilbertsoni* (Pl. V. fig. 9), and *P. leda*? (Pl. V. fig. 12) the radials are deeply notched, very much as they are in *Phænoschisma caryophyllatum* (Pl. XIV. figs. 1, 4).

In *Pentremitidea* and *Phænoschisma* (Pl. IV. figs. 9, 11, 13, 18), as in *Codaster* (Pl. XII. figs. 2, 5) and *Cryptoschisma* (Pl. V. figs. 23–26), the radials form the whole external surface of the calyx in its interradial regions; for the deltoids are

limited to the summit, except in *Pentremitidea leda*? (Pl. V. figs. 12, 13). The same is usually the case in *Troostocrinus* (Pl. V. fig. 21 ; Pl. XII. fig. 11), and also in *Tricœlocrinus* (Pl. XIX. fig. 13), both of which may have very deeply incised radials occupied by long ambulacra, so that the radial limbs extend close up to the mouth. But in *Pentremites* (Pl. II. figs. 1–7), *Mesoblastus* (Pl. VI. figs. 8, 12, 13), *Granatocrinus* (Pl. VIII. figs. 14, 16, 19), *Schizoblastus* (Pl. VIII. fig. 9), *Orophocrinus* (Pl. XI. fig. 9), and *Eleutherocrinus* (Pl. XIX. figs. 4, 6) the radial limbs are more or less roundly truncate and the ventral angles of the interradial areas between the ambulacra are occupied by the deltoid plates, which thus form the walls of the proximal ends of the radial sinuses, just as in *Codaster* (Pl. XII. figs. 1–6; Pl. XVI. figs. 1, 2). The deltoids are small in *Mesoblastus* and *Eleutherocrinus*, and the radial limbs therefore are proportionately long; while no true Pentremite has very large deltoids, their maximum development being reached in species like *P. ovalis*, Goldfuss, *P. robustus*, Lyon, and the *P. hemisphericus* and *P. basilaris* of Hambach, so that the greater part of the sinus is bounded by the radial limbs.

In *Granatocrinus* and *Schizoblastus*, however, there is a very great amount of variation in the relative proportions of the radials and deltoids upon the exterior of the calyx. In *Schizoblastus melonoides* the deltoids are small, so that the radial limbs appear in the ventral aspect at no great distance from the mouth (Pl. VI. figs. 15, 16). But in other species of the genus, notably in *S. Sayi* and *S. Rofei* (Pl. VIII. fig. 10), the radials are greatly diminished in size, and the deltoids form much the greater part of the calyx. *Granatocrinus Norwoodi* possesses very large radial plates, extending from the edge of the hollow base almost to the very apex of the calyx, and correspondingly small deltoids (Pl. II. figs. 32–36; Pl. VII. figs. 3, 5, 12). The proportions of the two are nearly equal in *G. ellipticus*, *G. orbicularis*, and in some forms of *G. campanulatus* (Pl. VIII. figs. 14, 16, 19; Pl. IX. figs. 11, 12); while in *G. Derbiensis* (Pl. IX. figs. 1–4, 6) the radials are reduced to a minimum, appearing as small pentangular plates, the apices of which are notched to receive the distal ends of the ambulacra, so that the radial sinus is almost entirely bounded by the deltoid plates.

The radials of *Granatocrinus Derbiensis* appear in a side view of the calyx; but in *Elæacrinus Verneuili* this is only slightly the case, the radials being almost entirely limited to the abactinal surface (Pl. II. fig. 46). They are notched for the ambulacra, and strongly recall the appearance of the ocular plates in the Urchins. In this genus the radial limbs are only represented by the two sides of the ambulacral notch; while, on the other hand, they reach a considerable size in many species of *Pentremitidea* and *Tricœlocrinus* (Pl. V. figs. 3, 6, 12, 17; Pl. XVI. fig. 18; Pl. XIX. fig. 13). The ambulacra are situated in the deep notch between them, and thus have a nearly vertical position, descending very rapidly outwards from the peristome, which is at the same level as the ventral ends of the radial limbs. In the remarkable genus

Stephanocrinus, however, and especially in *S. angulatus*, the elongated limbs of each radial diverge rather widely so as to form a capacious radial sinus (Pl. XIX. figs. 8–11). But this is not occupied by an ambulacrum descending from a peristome on a level with or above the ventral ends of the radials as in the Pentremitidæ; for the course of the ambulacra is almost horizontal, the peristome from which they start being nearly on the same level as the more or less distinct lip which marks the point of separation of the two limbs and the termination of the ridges which extend upwards from the dorsal surface of the calyx. The ambulacra thus lie at the bottom of a sort of funnel with deep notches cut in its rim, every two notches being separated by a prominent interradial process, of which the outer part is formed by the adjacent limbs of two contiguous radials and the inner part by a deltoid piece (Pl. XIX. figs. 8–12). The lower part of one of these prominent interradial processes is shown in fig. 11, but they are very rarely found preserved entire.

In all the Blastoids, except the Astrocrinidæ, the five radials are all equal and similar, as the basals would be were there sutures in the two large ones beneath the antero-lateral rays. But in the two remarkable genera which constitute this family the paired basals are altogether different from the azygos one, and the single radial which they jointly support is quite unlike its fellows (Pl. XIX. fig. 5; Pl. XX. fig. 15). These again are of two kinds, those right and left of the azygos radial being slightly different from the two which are opposed to it. Each of the four in *Eleutherocrinus* has a deeply notched sinus and nearly vertical ambulacra (Pl. XIX. figs. 4, 6). The azygos radial, however, is more like the radials of *Codaster trilobatus* (Pl. XIII. fig. 3), or of *Cryptoschisma Schulzi* (Pl. V. figs. 25, 26), and has no notch for the short ambulacrum, which simply terminates against its ventral edge without extending over this edge and down on to the side of the calyx (Pl. XIX. figs. 5, 6).

The same is the case in the flattened and more or less cruciform *Astrocrinus*. The azygos radial is somewhat rhomboidal, and notched for the tip of its ambulacrum (Pl. XX. figs. 15, 19, 20); while the four others group themselves into two pairs, in both of which the two limbs of each radial are somewhat unequal (Pl. XX. figs. 1–4, 11–14, 17, 20). This is only natural in the two rays C and E, which are next to the azygos one. But the adjacent limbs of radials A and B are often rather longer than their fellows, and form an interradial process which lies between the anterior ambulacra, and is more prominent than the two right and left of it.

The fork-pieces of *Pentremites* were spoken of by Say as the "scapulæ," the term employed by Miller for the first radials of *Platycrinus*, this being the type to which Say considered *Pentremites* to be most closely allied. Roemer[1] in like manner pointed out the resemblance of these plates to the radials of the Crinoid, and they

[1] Archiv f Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 344.

were generally called by this name, until Billings[1] asserted that they cannot represent the radials of a Crinoid because they do not support the bases of the ambulacra, which "are situated in the apex of the fossil, and do not come into contact with the forked plates. The apex of *Pentremites* is identical with the actinal centre of sea-urchins and starfishes, in which the mouth is situated. It is here that the ambulacra originate, and grow outward by the addition of new plates to their distal extremities. There can be little doubt that such was the mode of growth of the ambulacra of the *Pentremites*. The smaller extremity, therefore, of their ambulacra, which is received into the forked plate, is not the base, but corresponds with the apex of the ambulacrum of a sea-urchin or of a starfish. It also represents the tip of the arm of a Crinoid."

The distal end of the ambulacrum of *Pentremites* undoubtedly corresponds to the apex of the ambulacrum in an Urchin. But Billings also says that the bases of the ambulacra do not come into contact with the fork-plates of *Pentremites*, implying at the same time that the radials of a Crinoid do support the bases of the ambulacra. It appears to us, however, that the relation of the fork-pieces to the proximal ends of the ambulacra in *Pentremitidea* or *Troostocrinus* (Pl. IV. figs. 13, 14, 17, 18; Pl. V. figs. 4, 6, 15, 21; Pl. XII. fig. 11) is much closer than that between the radials of many Crinoids and the peristome in which their ambulacra originate. A comparison of the fork-pieces of *Codaster trilobatus* (Pl. XIII. figs. 3, 4), and of *Cryptoschisma Schulzi* (Pl. V. figs. 23–26), with the radials of *Platycrinus*, *Dichocrinus*, or *Hyocrinus* shows conclusively the identity of the two sets of plates. Each of them receives the distal end of an ambulacrum which starts from the peristome; and each alike may be said to support the base of the ambulacrum. But while the ambulacrum of the Blastoid goes no further than the radial, that of the Crinoid extends on to the arm-joints which are successively added beyond the radial, so that the tip or apex of the ambulacrum is carried further and further away from the calyx, to which it was at first confined.

In many Blastoids, as in many Urchins, the development of the interradial areas, whether due to the great size of the deltoid plates or to the length of the radial limbs, causes a considerable distance to intervene between the actinostome and the bodies of the radials which correspond to the ocular plates of the Urchins, so that the primitive relation of the radials to the ambulacra becomes somewhat obscured (Pl. IX. figs. 1–6). But the same is the case in many Palæocrinoids which have a largely developed interradial system between the primary arm-divisions, so that the cup increases considerably in size; and we do not see how there can be any doubt respecting the mutual homology of the fork-plates of a Blastoid, the radials of a Crinoid, and the ocular plates of an Urchin.

It may be noted further that the addition of an articular facet to the radial lip of

[1] American Journ. Sci. 1870, vol. l. p. 226; Ann. & Mag. Nat. Hist. 1871, vol. vii. p. 144.

the fork-piece in a *Pentremites* would cause it to be morphologically indistinguishable from the radial of the Mesozoic *Phyllocrinus*, the type which was formerly supposed to be a Neocomian Blastoid. The radials of this remarkable genus are closely similar in shape to those of a *Pentremites*. The lip is occupied by an articular facet, the lateral edges of which are produced upwards into two strong processes of varying length in different species. These bound a deep sinus which lodged the different arm-canals, surmounted by the ambulacral grooves radiating outwards from the peristome. The relation of the ambulacra to the radials, therefore, was rather more like that which they have in *Stephanocrinus* than the vertical position which they take in *Pentremites*. But this fact shows conclusively that the radials of a Crinoid and the fork-pieces of a Blastoid are homologous, plate for plate. It thus disproves Billings's assertion to the contrary, and also the theory which Wachsmuth and Springer[1] have expressed in the following terms:—"We may consider that the ambulacrum is a recumbent arm; the lower part of the forked plate up to the ambulacrum is the first radial . . . in *Blastoidocrinus*, the oldest-known Blastoid, the suture is visible . . . that the two sides of the fork, instead of being interradial, form together a second radial," &c.

We have unfortunately been unable to examine any specimens of *Blastoidocrinus*, which we only know from the figures of Billings and Schmidt. But we imagine the suture referred to by Wachsmuth and Springer to be that between the radials and deltoids, just as is shown in the hypothetical figure given by Billings[2], in whose interpretation of the calyx we entirely concur; and we have reason to believe that in this respect the American palæontologists are now in complete accordance with us.

E. The Deltoid Plates or Interradials.

Interscapular plates, *Say*.
Second series of suprabasals, *M'Coy*.
Superior plates, *Owen & Shumard*.
Deltoidstücke, *Roemer*.
Interradials, *De Koninck*.
Interradials, *Shumard & Yandell*.
Second radials, *Lyon*.
Deltoids, *Shumard*.
Interradials, *Hall*.
Interradials, *Meek & Worthen*.
Deltoids, *Billings*.
Deltoid pieces, *Hambach*.
Oral plates, *Etheridge, jun., & Carpenter*.
Oral plates, *Wachsmuth & Barris*.
Interradials, *Montgomery*.
Interradials, *Wachsmuth & Barris*.

From a purely morphological point of view the interradials are by far the most interesting of the three series of plates which together make up the calyx of a Blastoid. Basals and radials present themselves alike in every Crinoid, Urchin, and Stellerid; but the precise homologies in the unstalked Echinoderms of the

[1] "Revision of the Palæocrinoidea. Part I." (Proc. Acad. Nat. Sci. Philad. 1879, pt. 3), p. 13.

[2] "Figures and Descriptions of Canadian Organic Remains," Geol. Survey Canada, 1859, Decade iv. p. 20, fig. 8.

interradial plates of the Pelmatozoa have yet to be worked out; while the relation of the interradials to the hydrospires of a Blastoid renders them additionally interesting, both to the morphologist and to the systematist. They are of very variable size, sometimes as in *Schizoblastus Rofei* (Pl. VIII. fig. 9), *Granatocrinus Derbiensis* (Pl. IX. figs. 1, 2, 6), and *Elæacrinus* (Pl. II. figs. 43, 46), constituting almost the whole of the calyx; and sometimes, as in *Cryptoschisma* (Pl. V. fig. 24; Pl. XIII. fig. 20), *Phænoschisma* (Pl. XIV. fig. 11), and *Tricœlocrinus* (Pl. XIX. fig. 13), being entirely confined to the summit and almost invisible externally. Their proximal ends form the boundaries of the central mouth-opening, the angles of which are extended in the direction of the rays into five slits between their contiguous lateral edges (Pl. I. figs. 5, 6). A little further from the centre these edges meet one another, and form a suture which is naturally covered up by the ambulacral structures, and only becomes visible after they have been removed (Pl. I. figs. 6, 7; Pl. XII. fig. 13; Pl. XIV. fig. 12; Pl. XV. figs. 4, 10); or the summit ground away a little (Pl. XI. fig. 7; Pl. XII. fig. 9); or in an internal cast of the calyx (Pl. VI. figs. 18–20; Pl. VII. figs. 7–9).

Their general outline is either triangular, rhomboidal, or pentagonal. A good instance of the first type occurs in *Cryptoblastus melo* (Pl. VII. figs. 14, 15), the interradial sutures meeting the base of the triangle; while almost the same thing occurs in *Schizoblastus Rofei* (Pl. VIII. fig. 9), and in some forms of *Granatocrinus Derbiensis* (Pl. IX. fig. 6) which have a nearly horizontal radio-deltoid suture. In other types, however, such as *Granatocrinus ellipticus* (Pl. VIII. figs. 16, 19), *Codaster* (Pl. XIII. figs. 1, 4, 8), *Orophocrinus* (Pl. XI. fig. 9; Pl. XV. fig. 6), and in most *Pentremites* (Pl. II. figs. 1–9, 16–30) the radio-deltoid suture is strongly angular, so that the general outline of the interradial, as it appears externally, becomes rhomboidal, or even pentagonal if its proximal end is truncate, as sometimes occurs in *Granatocrinus Norwoodi* (Pl. VII. figs. 3, 10, 12). It must always be remembered, however, that the real lateral edges of the deltoid plates are concealed beneath the proximal ends of the ambulacra, and only become visible when the lancet-plate and its coverings have been removed (Pl. I. figs. 6, 7; Pl. XII. fig. 13; Pl. XV. figs. 4, 10). Internal casts, such as those of *Granatocrinus Norwoodi* figured on Pl. VII., are of special value in elucidating this point, the sutural edges of all the plates being indicated by more or less well-defined ridges on the surface of the cast.

Except for the presence of the spiracles round the mouth, the deltoids of the Blastoids have the same general relation to the hydrospires as the radials have. In *Granatocrinus Derbiensis* (Pl. IX. figs. 1, 2, 6), *Schizoblastus Rofei* (Pl. VIII. fig. 10), and in *Elæacrinus* (Pl. II. figs. 43–46) the sides of the long and narrow sinus are almost entirely formed by the deltoids, the radials being relatively very small, and only supporting the distal ends of the hydrospires. On the other hand, if the radials are long, as in *Granatocrinus Norwoodi* (Pl. II. figs. 32–36), *Pentremitidea leda*?

(Pl. V. fig. 12), *Mesoblastus elongatus*, and *M. angulatus* (Pl. VIII. figs. 1, 7), the deltoids take but little share in the formation of the narrow radial sinuses; and the greater part of the length of the hydrospires is supported by the radials, the deltoids appearing externally as small plates, or being absent altogether from the exterior of the calyx as in *Pentremitidea* (Pl. IV. figs. 9–14, 17, 18; Pl. V. figs. 1, 3, 6, 9, 17, 20). In other types, again, the deltoids are also entirely confined to the summit, and do not appear at all upon the exterior of the calyx, but the radial sinus is wide and nearly filled up by the ambulacra as in *Cryptoschisma Schulzi* (Pl. V. figs. 23, 24; Pl. XIII. fig. 20). In *Phænoschisma*, again, owing to the great length of the radial limbs the sinus is likewise deep, though it is but very imperfectly filled by the ambulacra. A good instance of this condition is afforded by *Phænoschisma nobile*, in which the radio-deltoid suture starts from the ventral end of the long interradial suture, and descends the sloping sides of the radial sinus towards the ambulacra (Pl. XI. figs. 1–3). The proximal or ventral part of the sinus in this and other species of the genus (Pl. XIV. figs. 9, 11, 12) is thus bounded entirely by the deltoid plates just as in *Cryptoschisma* (Pl. V. fig. 24).

In *Codaster pyramidatus* and *C. Hindei* there is a shallower and more open sinus, the walls of which are much less steep than in *Phænoschisma*, but traversed in the same way by the radio-deltoid sutures (Pl. XII. figs. 1–6); while in *C. trilobatus* the radials have no external limbs and the sinus is therefore non-existent, though the positions of its walls are indicated by the two triangular spaces on the flat summit in which the hydrospires are lodged (Pl. XIII. figs. 1, 4, 8), one on each side of the ambulacrum. Each of these is divided into two parts by the radio-deltoid suture. These sutures start from the middle points of the sides of the pentagonal cup so as to mark out a smaller and inscribed pentagon, the whole of which is composed of the five deltoid pieces surrounding the central mouth, just as in the slightly more concave summit of *Cryptoschisma* (Pl. V. fig. 24).

The genus *Heteroschisma* has been proposed by Wachsmuth [1] for the reception of three species which appear to him to differ from *Codaster* in the relation of the hydrospires to the interradial plates. We have pointed out [2] that *Phænoschisma* is distinguished by the presence of hydrospires in the anal interradius, and by the relatively small size of the interradials (Pl. XI. fig. 3; Pl. XIV. figs. 5, 11), while, according to Wachsmuth, *Heteroschisma* has small interradials like *Phænoschisma*, but resembles *Codaster* in having no hydrospires in the anal interradius. By this latter character, in our opinion, it is sharply distinguished from *Phænoschisma*; and we are here quite in accordance with Wachsmuth, who further tells us that he considers "the structural differences in the so-called 'oral plates' morphologically as important as the difference in the number of the hydrospires." The differences

[1] Report Geol. Survey Illinois, 1883, vol. vii. p. 252; Proc. Davenport Acad. Nat. Sci. 1885, vol. iv. p. 82.
[2] Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 227.

between the interradials of *Codaster* and those of *Heteroschisma*, as described by Wachsmuth, are so great that, did we believe them to exist, we should be compelled to place *Heteroschisma* in a separate family by itself. It appears to us, however, that Mr. Wachsmuth's description of *Heteroschisma* is an erroneous one—partly, we believe, from his not having clearly understood the real characters of *Codaster*. He tells us, for example, that the interradials of *Codaster* "rest with their lateral sides against the inflected upper part of the limbs, and form more or less strongly marked edges or elevated angular ridges, which extend out interradially from near the oral opening to the end of the plates. The hydrospires are placed to both sides of the so-called 'oral ridges,' and are located within the limits of the interradials, only small portions of them being continued along the sides of the limbs." He then goes on to contrast with these statements his description of the interradials of *Heteroschisma*. Unfortunately, however, the last sentence in the passage just quoted contains an error which affects the whole of Wachsmuth's subsequent account of *Heteroschisma*. In the first place, if the hydrospires of *Codaster* are all located within the limits of the interradials, it is difficult to see how even small portions of them can be continued along the sides of the limbs of the radials. The two statements are inconsistent. As a matter of fact, however, the hydrospires of the type species (*Codaster trilobatus*) are about equally distributed upon the radials and interradials, as is evident from a glance at figs. 1, 4, & 8 on Pl. XIII. The faint sutures which separate the diamond-shaped interradials from the limbs of the radials outside them were distinguished by Roemer in the better preserved among his specimens, and appear in two of his figures [1], while they are also shown in the diagram given by Billings [2]. We cannot but think that Mr. Wachsmuth must have altogether forgotten the position of these sutures when he committed himself to the statement that the hydrospires of *Codaster* are all located within the limits of the interradials. In the British *Codaster* the summit is nearly flat (Pl. XIII. figs. 3, 8–12), the ambulacra and the oral ridges lying a little above the general plane of the interradial areas. In *C. Hindei*, and more especially in *C. pyramidatus*, the summit is excavated in the direction of the ambulacra, which fall away towards their outer ends, so that they lie in shallow sinuses (Pl. XII. figs. 2, 5). The crest between every two radial sinuses is formed by the oral ridge, and from its outer end, where it meets the limbs of the radials, the sutures slant downwards and inwards so as to meet the ambulacra nearly at right angles, very much as they do in *C. trilobatus* (Pl. XII. figs. 1, 4; Pl. XIII. figs. 1, 4, 8). They are, however, difficult to see, and but for our previous experience with the British species we should probably never have detected them at all.

Now, according to Wachsmuth the summit of *Heteroschisma* is rather deeply

[1] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 383, Taf. v. figs. 2 *b*, 2 *d*.

[2] American Journ. Sci. 1869, vol. xlviii. p. 79, fig. 8; Ann. & Mag. Nat. Hist. 1870, vol. v. p. 261

excavated in the direction of the rays, and the edge or crest between every two sinuses is formed by the limbs of the radials. We do not hesitate to say that this would be a most anomalous condition, and one altogether unlike that which occurs in every other Blastoid. The oral crest of *Codaster* corresponds to the septum which is so often found in the spiracles of *Pentremites* with its extension outwards against which the side plates rest, and in no single instance are these parts formed by the limbs of the radials (Pl. I. figs. 5–7, 11). Both in *Phænoschisma* and in *Codaster*, which Wachsmuth admits to be the nearest ally of *Heteroschisma*, the oral ridge is formed by the interradials (Pl. XI. figs. 1, 3, 5–7; Pl. XII. figs. 1–6, 8; Pl. XIII. figs. 1, 4, 8; Pl. XIV. figs. 9, 11, 12), as is also the case in *Cryptoschisma* (Pl. V. fig. 24; Pl. XIII. fig. 20), *Tricœlocrinus* (Pl. XIX. figs. 13, 15), *Stephanocrinus* (Pl. XIX. figs. 8–12), and *Astrocrinus* (Pl. XX. figs. 2, 11, 12, 14–16); and we have good reason to believe that the same is the case in *Heteroschisma* also. According to Wachsmuth [1], the interradials of this type are "only partly exposed to view, the visible part occupying a small space round the mouth, the concealed portions, which give origin to the two inner hydrospires, being overlapped by the ends of two contiguous limbs. There is in *Heteroschisma*, in the proper sense of the word, exteriorly no 'oral ridge,' as the edge is here formed by the limbs. The limbs are extended interradially into high pyramids with steep sides, of which two of the walls form the sides of the radial sinus. The hydrospires are located, with the exception of the two inner ones, within the pyramids, being exposed along the sides of the sinus, nowhere connecting externally with the interradial plates." We do not dispute that the walls of the radial sinus in *Heteroschisma* at its outer end are formed by the limbs of the radials, just as in *Cryptoschisma* (Pl. V. fig. 24), *Phænoschisma* (Pl. XI. figs. 1–3), and *Codaster* (Pl. XII. figs. 1–6). But they take no part in forming the oral ridge, which starts from the apex of each pair of radial limbs on the exterior of the calyx, and is entirely located within the deltoid plates, just as in the genera above mentioned (Pl. X. figs. 19, 20; Pl. XVI. fig. 1). If the somewhat excavated summit be ground away, the concealed parts of the radial limbs on which the deltoids rest come to be more or less completely exposed, just as they would in *Phænoschisma nobile* (Pl. XI. figs. 1–3), or *Stephanocrinus* (Pl. XIX. figs. 8–12), though this is less evident in the more flat-topped *Codaster trilobatus* (Pl. XII. fig. 8); and it is, we think, in consequence of this that Wachsmuth has been led to interpret his section of the summit of *Heteroschisma* as indicating that the oral crest is formed by the radial limbs.

In his type species, *Heteroschisma gracile*, "intermediate between the ambulacra there are five pyramids, formed by the junction of the adjacent limbs of two contiguous radials, without the assistance of interradial plates." . . . . These last are "small, and only partly exposed to view, one half or more of each

[1] Proc. Davenport Acad. Nat. Sci. 1885, vol. iv. p. 83.

one being hidden beneath the radials. The exposed part, which consists of barely more than what might be called the lips of the mouth, is slightly projecting along the margin; it is in form rhomboidal, but the angle toward the radials is covered by the tips of the overlapping limbs. The concealed portions are longer than wide, and their distal end is somewhat extended outward and downward." Mr. Wachsmuth admits that "the description of the interradial plates was made from a specimen in which the greater part of the limbs had weathered away, thereby exposing the parts underneath;" and we cannot help thinking that he has been misled in consequence, partly, if he will forgive us for saying so, by his having forgotten the structure of the summit of *Codaster*. He has been kind enough to send us for examination no less than five specimens of *Heteroschisma gracile*, and has also informed us that the specimen belonging to him, which we figure on Pl. X. figs. 19, 20, as *Codaster alternatus*, Lyon, is his *Heteroschisma alternatum*, var. *elongatum*. We have therefore had six authentic examples of the genus for examination, and after studying them carefully we have come to the conclusion that it cannot be separated from *Codaster*. For in each specimen, though not in every sinus, we have found the sutures between radials and interradials in exactly the same position as they occupy in *Cryptoschisma* (Pl. V. fig. 24; Pl. XIII. fig. 20), *Phænoschisma* (Pl. XI. figs. 1–6), and *Codaster* (Pl. XII. figs. 1–6; Pl. XIII. figs. 1, 4, 8). It starts from the distal end of the oral crest where the latter meets the interradial suture, and it descends the sloping sides of the radial sinus cutting the hydrospires and ambulacra nearly at right angles, just as in *Codaster Hindei* and *C. pyramidatus* (Pl. XII. figs. 1–6; Pl. XVI. fig. 1). We do not wonder that these sutures have escaped Mr. Wachsmuth's notice, as they are not easy to see, and are only visible at all upon some of the sinuses. But after our experience with a large collection of the British species, we have no doubt as to the existence of the sutures, both in *C. Hindei* and in *C. pyramidatus*, and also in Mr. Wachsmuth's specimens of *Heteroschisma*. Owing to the circumstances of their position they are altogether different in appearance from the interbasal or interradial sutures, and manifest themselves by a kind of continuous break in the line of hydrospires, which is difficult to describe, but when once seen in *Codaster trilobatus* (Pl. XIII. figs. 1, 4, 8) is easily recognized in other species.

Thus, then, we believe that the principal character on which *Heteroschisma* was established has no existence in fact. Let us now pass on to those of a secondary nature.

Mr. Wachsmuth [1] says that "in *Codaster* the hydrospires enter the body nearly at right angles, and the walls are placed almost parallel to each other. In *Heteroschisma* the hydrospires stand obliquely to the sides of the sinus, and they are arranged closely round the mouth, while those of *Codaster* are placed away from the mouth." We are a little doubtful as to the meaning of the first sentence; but we cannot

[1] Proc. Davenport Acad. Nat. Sci. 1885, vol. iv. p. 83.

make out any difference in the relative positions of the hydrospires in *Codaster Hindei*, or of *C. pyramidatus* on the one hand (Pl. XII. figs. 1–6) and those of *C. alternatus*, var. *elongatus* (Pl. X. figs. 19, 20) and *C. gracilis* (Pl. XVI. fig. 1) on the other, which is not fully accounted for by the varying depth of the radial sinus. Neither can we see that the relative position of the hydrospires in *C. Hindei*, *C. pyramidatus*, or *C. trilobatus* (Pl. XIII. figs. 1–4, 8) is any further away from the mouth than in *C. alternatus*, var. *elongatus* (Pl. X. figs. 19, 20).

The deltoid plates of *Stephanocrinus* are worthy of special notice, more particularly as no figures of them in the type species (*S. angulatus*) have yet been published, and they were not known to occur in the genus at all until Hall [1] published his later figures of *S. gemmiformis*. This type has comparatively low coronal processes, which are principally formed by the limbs of the radials, though minute deltoids appear externally at their upper ends and form the descending oral crests on their inner faces. As regards *S. angulatus*, Hall's original description has been generally abandoned in favour of that which was subsequently given by Roemer [2]. The latter author nowhere described deltoid plates as actually present (partly, perhaps, because he believed *Stephanocrinus* to be a Cystid and not a Blastoid), but he saw indications of sutures extending downwards from the anal opening towards the ambulacra at its sides; and we now know that these are the radio-deltoid sutures which are visible in some of our specimens in other parts of the summit as well, though they are not always easy to see, except in a particular light. Each of the four coronal processes is thus divided into an outer portion, formed by the contiguous limbs of two adjacent radials, and an inner portion, the interradial, which reaches up to the apex of the coronal process as in *S. gemmiformis*. The anal opening is more or less distinctly visible in one of the processes, where it occupies the angle of the radio-deltoid suture; and in the corresponding position in some of the other processes there are occasional indications of a minute perforation (Pl. XIX. figs. 8–10), which is more distinct in specimens that have been slightly ground. Sometimes also traces of another and larger perforation of the same kind are visible, as shown in Pl. XIX. figs. 8, 10; and in summits that have been rubbed down the two openings in each coronal process appear as one which has a somewhat keyhole-like form, the outer end being the larger. It is probable that these openings are in some way related to the hydrospires; but upon this point we have no information at all. Neither are we quite clear as to the position of the interdeltoid sutures beneath the ambulacra; for even when the ambulacral structures are removed, as shown in three rays of the specimen represented in Pl. XIX. fig. 8, we cannot make out any sutural lines between the proximal ends of the deltoid plates such as are so visible in *Pentremites*

[1] "The Fauna of the Niagara Group in Central Indiana." 28th Ann. Rep. New York State Mus. Nat. Hist. Albany, 1879, pl. xiv. fig. 2.

[2] Archiv f. Naturgesch. 1850, Jahrg. xvi. Bd. i. p. 370.

(Pl. I. figs. 6, 7; Pl. XII. fig. 13) and in *Orophocrinus* (Pl. XV. figs. 4, 10). In one specimen, however, we have ground away a considerable portion of the summit so as to expose more of the tongue-like proximal ends of the deltoids, and their mutual relation seems to be very much that of the deltoids of *Pentremites pyriformis* represented in Pl. XII. fig. 13, viz. a close approximation near the peristome, and then a divergence as if to receive the hydrospires, of which we think that we can see some indications.

The deltoids of *Elæacrinus* present certain peculiarities which caused them for a long time to be altogether misunderstood, in spite of Roemer's excellent account of the structure of the calyx in this genus[1]. They are of very large size, and form the whole of the sides of the calyx, as the radials are quite small and limited to the dorsal region (Pl. II. fig. 46; Pl. XVIII. fig. 19). Each of them appears to consist of three parts, a median and two lateral ones, which are separated from it by more or less definite furrows and are transversely striated in correspondence with the markings on the linear ambulacra. Lyon and Billings were thus led to consider the central lanceolate portion as all that represented the deltoids, which, in the words of Billings[2], "taper to a point upward; and their sides are bevelled so as to pass under the ambulacral plates, to which they are in general so closely united that the line of junction is indicated only by the difference in the markings of the surface." It was first pointed out by Hall[3], however, and is now universally recognized, that the transversely striated marginal areas really belong to the deltoid plates, as was originally assumed by Roemer (Pl. II. fig. 46).

It is worthy of note that the large deltoid pieces of *Schizoblastus Sayi* often exhibit a triple division of their surface which is very similar to that presented by *Elæacrinus*. There is a lateral portion at the side of each ambulacrum which is sometimes striated longitudinally and sometimes transversely, according to the stage of the weathering, as in *Elæacrinus* (Pl. XVIII. figs. 16–18). This extends from the slit-like spiracle down to the radio-deltoid suture, and is sometimes continued, though reduced in width, down to the radial lip. The middle portion of the plate is somewhat depressed below the level of the marginal areas, and is continued beyond the spiracles into the tongue-shaped process which overhangs the peristome, and is marked by a small pit of variable size (Pl. III. figs. 1–3). The broad end of this lanceolate piece rests below upon the radio-deltoid suture; but the central depression of the interradial area is continued downwards on to the radial below and terminates by a pointed extremity between the radial lips.

We are convinced that the apparently tripartite division of the four anterior interradii of *Elæacrinus* is merely superficial, as in the case of *Schizoblastus Sayi*;

[1] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. pp. 376–379.
[2] Ann. & Mag. Nat. Hist. 1871, vol. vii. p. 147.
[3] Fifteenth Ann. Rep. New York State Cab. Nat. Hist. Albany, 1862, p. 147.

but on the other hand, we have little doubt that Hall[1] was right in describing the posterior deltoid as divided into two parts by an intercalated anal plate which had escaped Roemer's notice. Hall stated that he had never been able to find evidence of a distinct suture-line bounding the supposed lanceolate portion in the middle of either of the four normal interradii, "while on the anal side, the narrow plate which is nearly of the same form, is limited by a distinct suture-line."

Both Montgomery[2] and Barris[3], who have lately described new species of *Elæacrinus,* have adopted Roemer's analysis of the calyx as modified by Hall; and we think that there can now be no doubt that while the four anterior interradii of this genus are perfectly normal in their characters, the posterior deltoid is divided into two parts by an intercalated anal plate, as is well shown in Pl. XVIII. fig. 19.

The deltoids of the type which was described by Troost as *Pentremites Reinwardti*, and, in accordance with Shumard's suggestion, has since been generally known as *Troostocrinus Reinwardti*, appear to present a very striking peculiarity, of which we only became fully aware after the completion of our Plates and during the passage of this sheet through the press. In Roemer's first account[4] of the species, he described and figured the deltoids as appearing on the exterior of the calyx, and of about the same relative size as those of *Pentremites pyriformis* (Pl. II. figs. 24–30). But at the same time he stated that the interradial suture often appeared to reach the apex of the triangular area between every two ambulacra; and in a later account[5] he expressed his conviction that he had mistaken cracks in the calcite for the radio-deltoid sutures, and " dass in der That die seitlichen Nähte der Gabelstücke stets bis zur Spitze des Scheitels verlaufen und Deltoid-Stücke von der früher angenommenen Grösse und Lage also nicht vorhanden sind " (Pl. XII. fig. 11).

Hambach[6], however, subsequently figured an individual in which a relatively large deltoid really does appear externally, and we discovered another with the same peculiarity in the National Collection. We were quite inclined to agree with Hambach in regarding this as an anomalous development until we received a letter from Mr. Wachsmuth, in which he expressed his belief that the deltoid of the anal side always appears externally in this manner so as to truncate the two subjacent radial limbs; while the other four deltoids are not visible externally, the interradial sutures extending right up to the summit, as shown in our Pl. XII. fig. 11.

Mr. Wachsmuth's letter was accompanied by five specimens, two of which certainly bear out his statement, while the condition of the other three is not such as to enable us to speak decisively about them. But on reinvestigating the three examples of

[1] Ibid. [2] 'Canadian Naturalist,' 1881, vol. x. no. 2, p. 82.

[3] Proc. Davenport Acad. Nat. Sci. 1885, vol. iv. p. 89.

[4] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 373, taf. iii. figs. 12 *a*, 12 *b*.

[5] 'Die Silurische Fauna des westlichen Tennessee,' Breslau, 1860, p. 60, taf. iii. figs. 2 *a*, 2 *c*.

[6] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, p. 546.

this type in the National Collection, we find that each of them has a deltoid appearing externally in the anal interradius, though the suture-lines between it and the radials below are somewhat obscure. Together with Hambach's example, therefore, six individuals have been seen which present this peculiarity, viz. four deltoids limited to the summit, like those of *Pentremitidea Wachsmuthi* (Pl. V. figs. 6, 7), and one appearing externally on the anal side like those of *P. leda*? (Pl. V. fig. 12). Should this prove to be a universal character, it will be necessary, as Mr. Wachsmuth remarks, to separate *Troostocrinus Reinwardti* generically from *T. lineatus*, *T. Grosvenori*, &c., a point to which we shall return in the systematic portion of the catalogue.

F. On the Homologies of the Deltoid Plates.

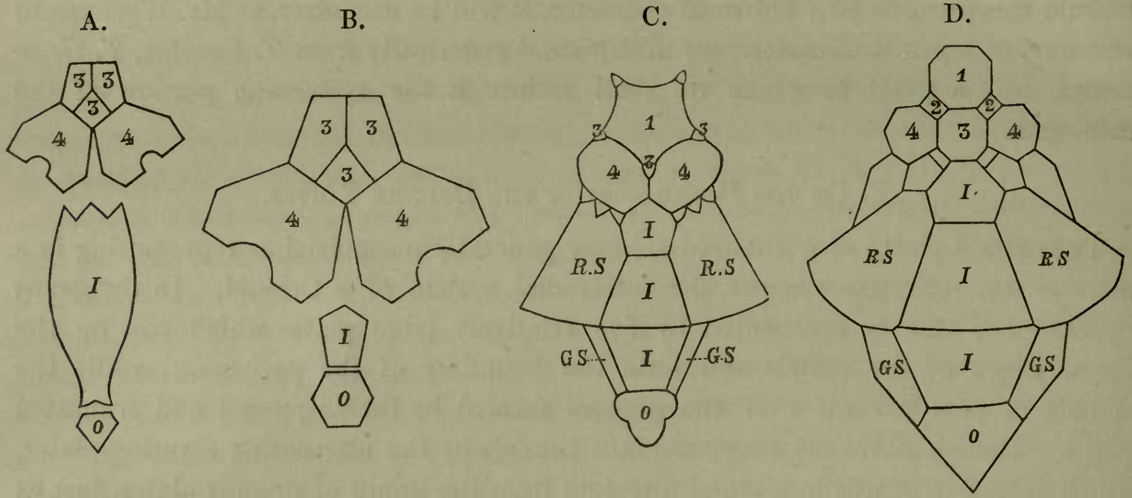
The deltoid plates of a Blastoid are now generally recognized as representing in a more or less collective manner the interradial system of a Crinoid. In the genus *Cyathocrinus* this is constituted by five relatively large plates which rest on the upper edges of the radials and form the boundary of the peristome; while the ambulacra pass inwards over the grooves formed by their apposed and truncated edges. These grooves are converted into tunnels by the alternating covering-plates, which extend outwards in a radial direction from the group of summit-plates, just as is the case with the ambulacra of the Blastoids (Pl. III. figs. 2, 3; Pl. VII. figs, 3, 4, 10–13; Pl. XV. figs. 11, 12). In *Cyathocrinus*, as in most Blastoids, there does not appear to be any great amount of regularity in the arrangement of the summit-plates. But in *Elæacrinus* it is not uncommon for each of the four normal interradii to have a single summit-plate corresponding to it, and two or more in the anal interradius, as shown in Pl. XVIII. fig. 16. Roemer[1] figures an extremely regular instance of this; while in Hall's diagram of *E. elegans*[2] only one summit-plate is represented on the anal side, so that the total number does not exceed five, a condition which is constant in *Stephanocrinus* (Pl. XIX. fig. 9). The summit-plates, therefore, are typically separated from the circle of united radials by one single plate, the deltoid, in each interradius (Fig. IV. A). This condition recurs in the simpler forms of *Platycrinus*, which have small interradials with the proximal dome-plates resting directly upon them (Fig. IV. B); and if the views be well founded which have long been advocated by one of us respecting the homology of these proximal dome-plates in *Platycrinus* with the orals of Neocrinoids and the mouth-shields of Ophiurids, there are many Ophiurids which are morphologically very similar to *Platycrinus* and the Blastoids. Thus, for example, in *Ophiomusium lunare* the large radial primaries on the dorsal surface of the disc are only separated from the mouth-shields on the ventral aspect by two interradials. There are three of these plates in

[1] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 378, taf. v. figs. 1*b*, 1*c*.

[2] Fifteenth Ann. Rep. New York State Cab. Nat. Hist. Albany, 1862, p. 153.

Ophioglypha minuta (Fig. IV. C), and they together represent the deltoids of *Elæacrinus* or the single calyx-interradial of the Bolland *Platycrinus*. In other Ophiurids, such for example as *Ophiomusium granosum* and *O. validum*, the interradial series starts from a basal, its lowest plate (or plates) separating two radials (Fig. IV. D);

Fig. IV.



Diagrams to illustrate the structure of the interradial area of the calyx between the actinal and the abactinal systems.

A. *Elæacrinus elegans* (modified from Hall). B. *Platycrinus*, sp. C. *Ophioglypha minuta*. D. *Ophiomusium validum*. (C and D adapted from Lyman.)

1. Dorsocentral. 2. Under-basals. 3. Basals. 4. Radials. *I.* Interradials. *R.S.* Radial Shields. *G.S.* Genital Scales. *O.* Orals.

and a parallel to this sometimes occurs in abnormal specimens of Blastoids, such, for example, as the *Pentremites sulcatus* figured by Hambach[1], in which two of the radials are separated by a long plate which rests on a basal below and supports the deltoid above.

The posterior deltoid of *Elæacrinus* is divided into two parts by the anal plate; and it may be noted that the same sort of arrangement occurs in many of the earlier Palæocrinoids, in which, however, the first anal plate often rests directly on a basal, and not on a radial, as in the Blastoid. Thus, for example, Wachsmuth and Springer[2] point out that in *Glyptaster*, *Eucrinus*, *Dorycrinus*, &c. "the first true interradial in the posterior area is divided, and is represented by two smaller plates, separated by a special anal plate." In *Glyptocrinus*, which has a complete radial ring, and also five regular interradials in the first series, there is the same general arrangement of

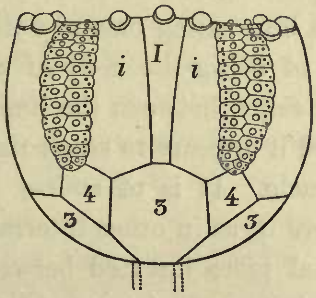
[1] Trans. St. Louis Acad. Sci. 1880, vol. iv. no. 1, p. 154, pl. B. fig. 11.

[2] 'Revision of the Palæocrinoidea,' part ii. (Proc. Acad. Nat. Sci. Philad. 1881, pt. 2), p. 13.

the anal area as occurs in *Glyptaster.* "The posterior area is distinctly divided into two equal parts by a single median row of plates. This row, which often extends to the anal opening, is composed of the true anal plates, but the plates on either side of it are interradials. By considering the latter, without regard to the median row, it will be found that the two sections taken together correspond exactly in number and in general arrangement with the interradials of the other areas, or at least differ not more than the other four differ among themselves."

Although the posterior or anal interradius of *Elæacrinus* is the only one which is definitely tripartite, yet there is a distinct tendency, both in this genus and in *Schizoblastus Sayi,* to an actual division of the interradial area into three longitudinal portions. This is of some interest as regards the relation of the Blastoids to the Urchins. For in the Triassic *Tiarechinus,* which has a remarkable superficial resemblance to an inverted Blastoid, the greater part of each interradial area actually

Fig. V.



Tiarechinus princeps, Laube, inverted so as to show the resemblance of its abactinal system to the calyx of a Blastoid. (The figure, but not the letters, after Lovén.)
3. Basal. 4. Radial. *I.* Single median interradial. *i.* Lateral interradials.

does consist of three plates, the two outer ones of which rest partly on the large basal and partly on the small radials, while the median one rests on a basal only (Fig. V.). The coincidence is a curious one, and is worth recording; but we have no desire to be understood as attributing any definite meaning to it, at any rate for the present.

G. Irregularities of the Calyx, and Monstrosities.

In the Blastoids, as in the Crinoids, slight irregularities in the structure of the calyx are not uncommon. A very insignificant one which we have noticed in *Cryptoschisma Schulzi* is shown in Pl. V. fig. 24. The distal end of one of the deltoids shows itself as a small diamond-shaped plate which caps the truncated limbs of the radials on the exterior of the calyx, though nothing of the kind is visible in

the other interradii. A similar development of the anal deltoid in some specimens of *Troostocrinus Reinwardti* has been already noticed.

Another variation in the condition of the deltoid is represented in Pl. VII. figs. 12 & 13, one of these plates in *Granatocrinus Norwoodi* being perforated by two spiracular openings, instead of by one only. This is obviously due to the fact that the two hydrospire-canals coming up from the radial sinus, as shown in Pl. VII. fig. 7, do not converge sufficiently to meet one another before opening externally on the surface of the deltoid. A similar slight variation, and one which is not uncommon in *Pentremites*, is for one or two of the ambulacra to be distinctly shorter than the rest, as is shown in Pl. II. fig. 9. It sometimes happens that the body of the radial, which is thus less deeply incised than usual, is considerably flattened instead of spreading outwards to its lip, as is normally the case.

Four- and six-rayed Blastoids are occasionally to be met with. The only case of the latter which we have seen occurs in a specimen of *Pentremites Godoni*, the dorsal surface of which is very regularly hexagonal. The usual ridges extend outwards over the basal cup, that corresponding to radius D being the weakest, as is normally the case. But the C ridge is a bifurcating one, and its left limb passes on to a plate which has all the appearance of being the body of a radial with the usual lip. It is continued up the side of the calyx, between the limbs of radials C and D, without being incised by any sinus, and it appears to reach right up to the summit, so as to assist in forming the anal spiracle. It is of course possible that there may be a partially concealed deltoid above it, as in other interradii; and it would then almost correspond to the "longitudinal piece inserted between two fork-pieces" which is figured by Hambach[1] in *Pentremites sulcatus*, except that the latter does not appear to have the characters of a radial below. But we are rather inclined to consider it as an unusually developed deltoid, *i. e.* interradial, which, instead of lying above the radials, as in *Cyathocrinus*, is in a line with them, as the interradials are in the Rhodocrinidæ; while at its lower end it takes on all the characters of a radial, except that it is not incised to receive an ambulacrum.

The tetra-radiate condition appears to be to some extent the reverse of this,—viz. a radial losing its ambulacrum and appearing as a flattened plate with traces of a median ridge, and a tendency to the formation of a lip just above the basi-radial suture (Pl. II. fig. 11), so that the base of the calyx is almost normally pentagonal. But there are only four ambulacra proceeding from the summit and four spiracles separating them. The summit of a distorted specimen of this kind is figured in Pl. II. fig. 10. We have seen three examples of *Granatocrinus Norwoodi* which present this character in very varying degrees. In two of them the dorsal aspect of the calyx is toleıably normal, but the fifth radial (C) is more or less undeveloped. It either only reaches halfway up the calyx, or it spreads out above

[1] Trans. St. Louis Acad. Sci. 1880, vol. iv. no. 1, p. 154, Pl. B. fig. 11.

the pseudo-lip into a broad plate which lies between the limbs of radials B and D, and abuts at the summit against the two posterior deltoids, the shape of which is considerably distorted. Although distinctly a radial at its lower end, its upper part has very much the relations of the anal plate of *Elæacrinus*, if allowance be made for the fact that the radial sinus of the latter is almost entirely bounded by the deltoids, and not by the radial limbs, as is the case in *Granatocrinus Norwoodi*.

In a third individual of the latter species (Pl. II. fig. 36) the D ray is replaced by a large and wide plate, which bulges out very considerably so as to distort the shape of the calyx a good deal. It starts from the edge of the basal concavity, but has no definite lip; though in other respects it resembles the intercalated plate of the two individuals just described. For it separates the limbs of radials C and E, and abuts at the summit against the outer ends of the anal deltoid and of its neighbour on the right. It is doubtful whether there is any deltoid at all in the next interradius (A–E), as the anterior limb of radius E seems to extend right up to the peristome and to be pierced by the spiracle.

Another curious modification of the Pentremite-type is shown in Pl. II. fig. 12. The summit, which is rather distorted, has the usual five ambulacra, though there is no groove on the lancet plate of C. But its place is occupied by a strong median ridge, which is faintly marked by the usual cross striation. This ridge is still more prominent in the B ambulacrum of a tetraradiate specimen, and it has a spiracle-like opening at its proximal end (Pl. II. fig. 8).

Irregularities and inequalities of growth may not unfrequently be observed in the hydrospire-sacs. Thus in the ambulacral section of *Pentremites sulcatus*, which is represented on Pl. XVIII. fig. 5, four hydrospire tubes appear on one side and six on the other; and Hambach[1] has figured similar inequalities in three other species of *Pentremites*.

[1] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, p. 544.

CHAPTER III.

THE AMBULACRA.

Those parts of the organization of a Blastoid which go by the general name of the "ambulacra" form five radiating zones of variable width, that extend outwards from the mouth in the centre of the summit, and are of very different lengths in different genera. Whereas in *Cryptoschisma* (Pl. V. figs. 23–26), *Stephanocrinus* (Pl. XIX. figs. 8–10), and *Codaster trilobatus* (Pl. XIII. figs. 1, 4, 14) the ambulacra are entirely limited to the ventral surface of the cup, those of *Elæacrinus*, *Granatocrinus*, *Mesoblastus*, *Schizoblastus*, and of some *Pentremites* extend downwards along the whole height of the calyx, and pass on to its dorsal surface (Pl. II. figs. 1, 14, 32–35, 43, 46; Pl. V. figs. 14, 29; Pl. VI. figs. 12, 14, 15, 17, 23), sometimes only terminating at the edge of the hollow in which the basals are lodged (Pl. VIII. figs. 8, 18; Pl. IX. figs. 3, 13). Consequently, in such types as these, the ambulacra have a very great resemblance to those of an *Echinus*, especially as they are constructed of closely-fitting limestone plates, and in the more typical Blastoids have a series of pores along their margins (Pl. I. figs. 1–3; Pl. VIII. figs. 5, 21; Pl. IX. figs. 5, 7, 14–16). It is not surprising, therefore, that Say[1], the founder of the group Blastoidea, and also of its originally single genus *Pentremites*, should have been led to infer that these pores served for the transmission of respiratory tubes, and that the Blastoidea "constitute the link between the Crinoidea and the Echinidea."

The subsequent researches of Roemer, Rofe, Billings, and others have, however, revealed the fact that the marginal pores of the ambulacra can have had no relation to a median water-vessel, as is the case in the Urchins; while four different generic types have been discovered in which there are no pores at all along the margins of the ambulacra. Nevertheless Say's doctrine has been recently revived by Hambach, whose statements concerning it will be discussed further on.

A. The Lancet-plate and its Internal Relations.

The various structures which enter into the composition of the ambulacra of a Blastoid will probably be most readily understood if we commence our study with the type genus *Pentremites*, which was so carefully investigated by Roemer. In like manner we think it desirable to begin by describing the ambulacra as they appear in

[1] Journ. Acad. Nat. Sci. Philad. 1825, vol. iv. pt. 2, pp. 292, 293.

by far the greater number of specimens collected, leaving for subsequent consideration the covering-plates which roof in their median grooves (Pl. I. fig. 8; Pl. XV. fig. 12), and the so-called pinnules at their sides, which are but rarely found preserved (Pl. III. fig. 13; Pl. XI. figs. 16, 17).

The ambulacra of *Pentremites*, as usually exposed, are five broad and more or less petaloid areas, which radiate outwards from the peristome towards the dorsal part of the calyx (Pl. I. figs. 1–6; Pl. II. figs. 1–7, 14–30). Each of them is marked by a median groove, which continues the outward extension of the radial angles of the mouth between the proximal ends of two adjacent interradial plates. This groove, which in perfect specimens is roofed in by the covering-plates (Pl. I. fig. 8), is continued down the median line of the ambulacral field, being much more marked in some forms than in others, and terminates against the body of the radial which supports it (Pl. I. fig. 2; Pl. III. figs. 5, 7; Pl. XVI. fig. 22). It corresponds, as we believe, to the food-grooves on the disc and arms of a Crinoid, and it may therefore be termed the ambulacral groove. It occupies the median line of the broad lancet-plate, as it was well called by Roemer. This fills up the central portion of the ambulacral field, the space between its lateral edges and the sides of the radial sinus being occupied by the side plates or pore-plates of Roemer (Pl. I. figs. 1–3, 5, 6; Pl. XII. figs. 13, 14; Pl. XVI. fig. 21). The ambulacral field is thus traversed from end to end by two lines of suture, which separate the median lancet-piece from the side plates at its edges, as is well shown in Pl. I. figs. 3, 5, 8, 9. They are not always visible, however, only appearing in specimens which have undergone a certain amount of weathering, as pointed out by Roemer [1]. The lateral edges of the lancet-piece are very well seen in specimens from which the side plates have fallen away more or less completely, as shown in Pl. I. fig. 5. This individual, and also the *Pentremites robustus* represented on Pl. XVI. fig. 21, show very well the boundaries of the lancet-plate at its proximal end, where it lies over the suture between two adjacent deltoids. This point is still better illustrated, however, in the specimen of *Pentremites pyriformis* represented in Pl. I. figs. 6 & 7. The lancet-plate of one ambulacrum is intact, though its proximal side plates have fallen away, thus increasing the size of the spiracular openings; while in the two other ambulacra the lancet-plate is altogether removed, though its shape is indicated by the deep impression of its under surface in the proximal ends of the deltoid pieces. On the left-hand side of fig. 6 a fragment of the lancet-plate has remained behind in the deepest part of this impression, while on the right it has been entirely removed, as is shown more clearly in fig. 7.

The relations of the central end of the lancet-plate are, however, seen best of all in another specimen of *Pentremites pyriformis*, which we owe to the kindness of Dr. G. J. Hinde (Pl. XII. figs. 13, 14). It is evident from this preparation that the under side of the lancet-plate is by no means so simply constructed as its upper surface. The

[1] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. pp. 333, 334.

proximal end bears a large median process, shaped like an elongated shield. Its surface rises rapidly from the sides towards the centre, which is produced into a strong ridge or keel; and it is the most prominent part of this keel which remained behind in the specimen shown on Pl. I. fig. 6. The lateral margins of the apposed deltoid plates are bevelled away so as to form a sort of trough which receives this shield-shaped process, the interdeltoid suture being visible at the bottom of the trough. Rather beyond its middle, and therefore at its deepest part, there is an opening which leads into the interior of the calyx. It is shown, though less distinctly, in Pl. I. figs. 6 & 7; and we have also found it in *Granatocrinus ellipticus*, *Phænoschisma acutum*, and *Orophocrinus verus* (Pl. X. fig. 15; Pl. XIV. fig. 12; Pl. XV. fig. 4). It was first discovered by Wachsmuth & Springer, whose description of it will be considered immediately; and as we agree with them in regarding it as "equivalent to the opening at the base of the arms in Palæocrinoids" [1], we propose to call it the ambulacral opening. The interdeltoid suture in our specimen of *Pentremites pyriformis* is only continued a very short distance beyond the ambulacral opening, the truncated edges of the deltoids becoming less and less marked, so that the excavation between them terminates at a point which corresponds to the distal end of the shield-shaped process beneath the lancet-plate (Pl. XII. figs. 13, 14). The central ends of the inner hydrospire-folds abut against the sides of these bevelled edges of the deltoids; and the latter are received in a V-shaped notch at the proximal end of a slightly concave plate with a median groove, which we propose to call the "under lancet-plate." It is shaped like the lancet-plate in miniature, and in its hollow there rests a low prismatic ridge, which occupies the median line on the lower surface of the broad lancet-plate. Its pointed proximal end comes into contact with the distal end of the shield-shaped process above described, as is well shown in Pl. XII. fig. 14. In this remarkable specimen the lancet-plate has broken across rather beyond half its length from the mouth, bringing with it the whole of the two ridges on its under side and a few side plates at its edge. The relations of the under lancet-plate are thus admirably exposed. It is very thin, and has a faint groove in the middle of its upper surface, which is slightly concave and lancet-shaped in outline. The plate is not sufficiently wide, however, to come into direct contact with the grooved and sloping sides of the radial sinus, except towards its distal extremity; for it only corresponds in width to the prismatic ridge on the under surface of the lancet-plate, and not to the whole of the latter. Some of the hydrospire-clefts and ridges are therefore left uncovered, and are visible at the sides of the under lancet-plate when the lancet-plate is removed. In other species, however, the under lancet-plate is much wider, extending right across the radial sinus, and completely concealing the hydrospire-apparatus (Pl. XII. fig. 16).

[1] "Revision of the Palæocrinoidea," Part I. (Proc. Acad. Sci. Philad. 1879, pt. 1), Explanation of pl. iii. fig. 4.

This plate seems to have altogether escaped the notice of Roemer, who figures the hydrospires of *Pentremites Godoni* as four on each side [1], all completely visible after removal of the lancet-plate, which doubtless brought away the under lancet-plate with it. Wachsmuth and Springer give a diagrammatic figure [2] of its relations in *Pentremites*, the species illustrated, though not named, being one in which this plate is narrow, and only occupies the middle of the radial sinus. It is called the "inner lancet-plate," and is said to have a tubular passage running lengthwise through it, whilst the lancet-plate is figured in section as altogether imperforate.

Hambach [3], however, states that the lancet-plate of *Pentremites sulcatus* contains a minute longitudinal canal, and he describes its inner face as "concave, semilunar, and grooved in its whole length for the reception of some duct or vessel;" while, according to Roemer [4], the lancet-plate on its inner face is "zu einer flachen Längsrinne ausgehöhlt." He gives no figure showing this groove, but Hambach [5] does, and from a comparison of Hambach's figure with our own dissection of a *Pentremites*-ambulacrum we are inclined to think that this longitudinal furrow of the lancet-piece is merely the impression of the prismatic ridge on its under surface which we have described above. Our supposition that this prismatic ridge is the duct or vessel which Hambach mentions as lying beneath the lancet-piece, seems the more probable because he says [6] that "the calcareous substance which is frequently found to fill out the duct, or the upper blade of the hydrospiric sac, which is smooth and overlies the plicas, may mislead to the supposition of having here a sublancet-plate." It may be noted too that in his figure of a restored ambulacrum, on the same page, this duct is represented as a plate of the same solid nature as the pore-plates, without any indication of perforation such as he gives for the "canal perforating" the lancet-piece.

We cannot therefore confirm Hambach's description of any duct, vessel, or canal beneath the lancet-plate of *Pentremites*; and we are strongly inclined to believe that he is in error when he describes this duct as "resting in the concave furrow of the lancet-piece, and running from the apex of the ambulacral field to the summit, where it connects with a circular duct [œsophageal ring?] surrounding, on the interior side, the central orifice or *annulus centralis*. This I have been so fortunate as to obtain entire from a well-preserved specimen of *Pentremites Norwoodi*; though, being probably composed of a very fine and delicate tissue or membrane, it is destroyed in most cases, and therefore very rarely observed" [7].

1 Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. Taf. i. fig. 3.
2 "Revision of the Palæocrinoidea," Part I. pl. iii. fig. 4.
3 Trans. St. Louis Acad. Sci. 1880, vol. iv. no. 1, p. 149.
4 Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 333.
5 Trans. St. Louis Acad. Sci. 1880, vol. iv. no. 1, pl. A, fig. 9.
6 *Ibid.* No. 3, p. 532.
7 *Ibid.* No. 1, p. 151.

Thanks to the kindness of Mr. Wachsmuth we are now in a position to understand the nature of the circular duct which Mr. Hambach has obtained entire in *Pentremites Norwoodi*. We have three specimens which show portions of it and of its radial extensions (Pl. VI. fig. 19), and we are satisfied that the latter represent the canals within the lancet-pieces, as we shall explain subsequently. According to Hambach, however, this circular duct unites the radial vessels beneath the lancet-pieces which he thinks he has seen in the typical *Pentremites*. But it is by no means clear that he has seen these "sublancet" vessels in *Granatocrinus Norwoodi*; and we are inclined to think, as we have pointed out before [1], that he has seen his so-called "longitudinal duct" in a typical *Pentremites*, and the circular duct in *P. Norwoodi*, which is the typical *Granatocrinus*. But why does he consider this circular duct as uniting a series of longitudinal ducts *beneath* the lancet-pieces, rather than as the oral ring for the system of canals which he correctly describes within the lancet-pieces themselves?

These are relatively large canals, and were first discovered by Rofe [2], who, however, misinterpreted their nature: they were figured by Wachsmuth and Springer [3] in *Granatocrinus Norwoodi*, and are shown in our Pl. XVII. in *Granatocrinus* (figs. 4–8), *Mesoblastus* (figs. 9, 10), *Orophocrinus* (figs. 12, 13), and in *Eleutherocrinus* (Pl. XIX. figs. 2, 3). We are inclined to think therefore that Hambach is right in stating that the lancet-piece of *Pentremites* is perforated by a canal. For we seem to have evidence of such a canal in our sections of the ambulacra of *Pentremites pyriformis*, *P. elongatus*, and *P. conoideus* (Pl. XVIII. figs. 3, 4, 6). When the summit is rubbed down, it is then evident, as stated by Hambach [4], that "these canals are only the radiating rays of a pentagonal ring surrounding the central orifice." According to his descriptions, therefore, there are two rings round the central orifice, one which he and we ourselves have seen in *Pentremites* uniting the canals within the lancet-pieces, and one uniting the sublancet-canals, which Hambach has obtained entire from a well-preserved specimen of *Granatocrinus Norwoodi*. We believe, however, that this is the same ring as appears in rubbed specimens of *Pentremites* uniting the lancet-canals (Pl. XII. figs. 15, 17). Its relation to these canals in *Granatocrinus Norwoodi* is very evident in our specimens (Pl. VI. fig. 19); and Hambach offers no proof whatever of the existence of a second ring in this species, nor of any longitudinal duct beneath the lancet-piece, such as he describes in *Pentremites*.

It is just possible that the under lancet-plate with a tubular passage running through it which is shown by Wachsmuth and Springer [5] in their section of *Pen-*

[1] Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 219.

[2] Geol. Mag. 1865. vol. ii. p. 249.

[3] "Revision of the Palæocrinoidea," Part. II. pl. xix. fig. 6.

[4] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, p. 538.

[5] "Revision of the Palæocrinoidea," Part. I. pl. iii. fig. 5.

tremites pyriformis may be the duct or vessel described by Hambach in the same position. But we are inclined to doubt this for various reasons; and we think it far more probable either that Wachsmuth and Springer have really seen the canal within the lancet-piece, but in a position rather nearer the dorsal surface than it often occupies, or that the passage which they describe within the inner lancet-piece is merely the median groove upon its upper surface, as shown in our figures (Pl. XII. figs. 13, 16), and that all the calcareous tissue above this really belongs to the lancet-piece. But we have no doubt that they are right in noting the presence of an under lancet-piece. Hambach[1] says, however, that he must deny its existence, "and would advise Mr. Carpenter, before making such assertions, to examine the matter more carefully; for the truth of the matter is, that there is no such thing as a sublancet plate, and what has been taken for it is only the upper blade of the hydrospiric sac, or the calcareous substance from the duct above it; because immediately under the lancet plate lies a duct or vessel (as already described in my paper), and under this the hydrospiric sac. I hardly deem it necessary to give a definition of the difference between the above-named organ and a sublancet plate, which latter could only mean a something like the lancet plate, only underlying it."

This, however, is precisely the meaning which we intended to convey with regard to the under lancet-plate of *Orophocrinus* and *Pentremites*, the only two genera in which we have noted its presence. Hambach's denial of its existence, although couched in very general terms, is perhaps not meant to apply to *Orophocrinus*, as he only professes to be writing about "the Pentremites." At any rate we do not think that our statement will be questioned by those who examine our figures of it in *O. verus*, *O. pentangularis*, and *O. stelliformis* (Pl. XV. figs. 4, 10, 13). In the last-named species it forms a sort of shallow trough in which the lancet-piece lies; and it meets the sides of the radial sinus immediately beyond the radio-deltoid suture, so that the hydrospire-clefts of other Blastoids are here reduced to the short and linear spiracular openings at the proximal ends of the ambulacra. These are rather short in the specimen represented in Pl. XI. fig. 9 and in Pl. XV. fig. 13; and they appear still shorter in the latter figure, owing to the position in which the ambulacrum is drawn. The proximal end of the under lancet-plate is not seen, as it is concealed beneath that of the broken-lancet piece, but its relations are very well shown in a specimen of *Orophocrinus verus* (Pl. XV. fig. 4). One ambulacrum has lost the whole of the lancet-plate except its distal end, so that the relations of the under lancet-plate to the deltoids and to the ambulacral opening are very well seen. This opening is not situated entirely between the deltoid pieces as in *Pentremites pyriformis* (Pl. I. figs. 6, 7; Pl. XII. fig. 13), but its hinder border is formed by the under lancet-plate, just as is figured by Wachsmuth and Springer[2] in their general diagram of a *Pentremites*. The proximal end of the under lancet-plate is more deeply hollowed than the distal

[1] Trans. St. Louis Acad. 1884, vol. iv. no. 3, p. 538.

[2] "Revision of the Palæocrinoidea," Pt. I. pl. iii. fig. 4.

part, just as we have found to be the case in one form of *Pentremites pyriformis* (Pl. I. figs. 6, 7). As in that species too, the under lancet-plate is not wide enough to cover and conceal the hydrospire-slits at the proximal end of the radial sinus; though it comes into contact with the radials for about one third of its length, just as is the case, though in a greater degree, in *Orophocrinus stelliformis* (Pl. XV. fig. 13). On the other hand the under lancet-plate of *Orophocrinus pentangularis*, so far as can be judged from the fragment of it which remains, is narrow and linear, not meeting the radials, and so hardly covering the hydrospires at all (Pl. XV. fig. 10).

We do not think therefore that the presence of an under lancet-plate in *Orophocrinus* will be doubted any longer. That of *Pentremites* is much thinner and altogether less substantial, a fact which may have misled Hambach into regarding it as "the upper blade of the hydrospiric sac." It is quite true that this does appear to be the case in specimens like the *P. Godoni* represented in Pl. XII. fig. 16, in which the under lancet-plate extends right across the radial sinus, and completely conceals the hydrospires. But this explanation is useless for those forms in which this plate is narrow relatively to the ambulacra, so that the hydrospires are visible at its sides as in *P. pyriformis* (Pl. I. figs. 6, 7; Pl. XII. fig. 13). These species are in the same relation to *P. Godoni* as *Orophocrinus pentangularis* to *O. stelliformis* (Pl. XV. figs. 10, 13); and if Hambach be right in regarding the under lancet-plate of *Pentremites* as merely "the upper blade of the hydrospiric sac," this sac must be open above in *P. pyriformis* along a considerable length of the ambulacrum; but the section represented on Pl. XVIII. fig. 3 shows that this is not the case. Then, again, the under lancet-plate is essentially a mid-ambulacral structure, occupying the median line of the radial sinus; but if, as supposed by Hambach, it is the upper blade of the hydrospiric sac, it should appear as a double plate with a long slit between its two halves leading down into the cavity of the calyx, such as is actually present in *Granatocrinus ellipticus* (Pl. X. fig. 12). For the hydrospire-folds on the two sides of the ambulacrum do not always meet one another so closely as is represented in Hambach's "transverse section of a restored ambulacral field "[1]. Thus for example in all the five species of *Pentremites* in which we figure the hydrospires, and also in Wachsmuth and Springer's section of *P. pyriformis*[2], there is a more or less wide gap between the innermost lamellar tubes on the two sides of the ambulacrum (Pl. XVI. figs. 19, 20; Pl. XVIII. figs. 3–6). This is well marked in both our varieties of *P. pyriformis*, in which the under lancet-plate is very clearly visible in the median line of the sinus (Pl. I. fig. 7; Pl. XII. fig. 13), though, from Hambach's explanation of its nature, it has no business there. Unlike Wachsmuth and Springer, we have failed to see the under lancet-plate in transverse section, not having been able to cut any other specimen in which it is so distinctly

[1] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, p. 538.

[2] "Revision of the Palæocrinoidea," Part I. pl. iii. fig. 5.

separable from the lancet-plate as in Dr. Hinde's example of *P. pyriformis*. But we are quite clear that neither of Hambach's suggestions as to its nature is anywhere near the truth. He intimates that we may have been misled by "the calcareous substance which is frequently found to fill out the duct" beneath the lancet-plate. We do not think this probable, as we have never seen the duct in question. We have sometimes found a groove along the under surface of the lancet-piece in other types (Pl. XVII. figs. 1, 11), but we cannot make out that anything else was contained in it besides the calcite usually found in the interior of the calyx.

In the genera *Mesoblastus*, *Granatocrinus*, and *Cryptoblastus* there is no under lancet-plate. But the alternating folds and slits of the hydrospires are not thereby exposed when the lancet-plate and side plates are removed, as would be the case in *Pentremites* (Pl. I. fig. 7; Pl. XII. fig. 13). For the hydrospire-slits are covered up at each side of the ambulacrum by what we have called the "hydrospire-plate[1]" (Pl. IV. fig. 4; Pl. VI. fig. 10; Pl. VII. fig. 15; Pl. VIII. fig. 20; Pl. IX. fig. 16; Pl. X. figs. 11, 12, 14; Pl. XI. figs. 11–15). The inner wall of each hydrospire-sac, *i. e.*, that forming the boundary of the hydrospire-canal into which the lamellar tubes open, is more substantial than in *Pentremites*, and it is produced upwards above the openings of these tubes towards the ventral surface of the ambulacrum, until it comes into contact with the sides of the radial sinus. This is very well shown in the weathered specimen of *Granatocrinus ellipticus* which is represented on Pl. X. fig. 14, the hydrospire-plate being distinctly visible between the lancet-piece and the radials. This species has very narrow ambulacra, and the two hydrospire-plates rise somewhat steeply, leaving only a narrow median slit between them, which leads down into the interior of the calyx (Pl. X. fig. 12). The lancet-piece is wedged in between them and so covers this slit. The same is the case in *Granatocrinus Derbiensis*, except that the hydrospire-plates are even steeper than in *G. ellipticus*, so that the cleft between them, at any rate at the tip of the ambulacrum, is wider than in that species (Pl. XI. figs. 11–13). *G. campanulatus* is another form of the same kind. The lancet-plate is broad, and supports the whole of the side plates, so that hardly anything of the hydrospire-plate is visible at its sides (Pl. VIII. fig. 15). But in *Mesoblastus Rofei*, *M. crenulatus*, *M. elongatus*, and *Granatocrinus Norwoodi* (Pl. IV. fig. 4; Pl. VI. fig. 10; Pl. VIII. fig. 6; Pl. X. fig. 11; Pl. XI. fig. 14), the hydrospire-plates come up towards the ventral side much less steeply, so that the lancet-plate is relatively lower. The consequence is, that the side plates instead of resting entirely on the lancet-piece, as in *Granatocrinus campanulatus* and *G. ellipticus* (Pl. VIII. fig. 15; Pl. X. fig. 12), are partly supported by the hydrospire-plate, which is moulded to receive them, just as the upper surface of the lancet-plate is. This condition is especially well marked in *Mesoblastus Rofei*, and also in *M. crenulatus*, owing to the relatively small size of the lancet-piece and the large amount of hydrospire-plate, which is thus exposed (Pl. IV. fig. 4; Pl. VI. fig. 10). It

[1] Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 215.

also seems to present itself in *Mesoblastus Sowerbyi* and in *M. elongatus* (Pl. VI. fig. 13; Pl. XI. fig. 15), though the markings on the upper surface of the hydrospire-plate have been worn away in our specimens. The difference between the well-defined hydrospire-plates in the genera above mentioned and the under lancet-plate of *Pentremites* is very evident. The former belong to the sides of the ambulacra and do not meet beneath its middle line, where a more or less wide gap is left between them, leading down into the interior of the calyx (Pl. X. figs. 11–14; Pl. XI. figs. 11–15). The under lancet-plate of *Pentremites* and *Orophocrinus*, however, occupies the middle of the radial sinus, and may or may not reach its edge (Pl. I. fig. 7; Pl. XII. figs. 13, 16; Pl. XV. figs. 4, 10, 13). Its distinctness from the inner walls of the hydrospire-sacs is well shown in *Orophocrinus pentangularis*, where it is partly broken away, and is seen to be resting upon the truncated edges of the two walls in question (Pl. XV. fig. 10).

The under lancet-plate in these two types is not therefore, as Hambach[1] has asserted, "the upper blade of the hydrospiric sac, which is smooth, and overlays the plicas." He says that this "may mislead to the supposition of having here a sublancet-plate." So far as regards *Granatocrinus*, we are quite in accordance with him upon this point, having described the hydrospire-plate two years before he noticed it; but at the same time we expressly stated that this genus had no under lancet-plate, mentioning also that we could confirm Wachsmuth and Springer's discovery of an under lancet-plate in *Pentremites*, and that we had likewise found it in *Orophocrinus*[2]. Hambach's attempts to explain it away were therefore not wanted for *Granatocrinus*, in which genus it has never been described, while, as shown above, they do not suit the conditions of its occurrence in *Pentremites* and *Orophocrinus*.

Reference has already been made to the very general, if not universal, presence of a canal within the lancet-piece of a Blastoid. It was first seen, though misinterpreted, in *Granatocrinus ellipticus* by the late Mr. J. Rofe[3], who figured it as seen in section in the original of our Pl. X. fig. 13. But finding a large number of weathered specimens, like that represented on Pl. VIII. fig. 20, he was led to suppose that this lancet-plate "is in reality a compound plate formed of two contiguous plates," each of which is interradial in position, and goes to form the lancet-plates of two ambulacra; and he described how in many weathered specimens these two parts "appear to meet only at the top and bottom of the cross section, leaving a lozenge-shaped opening between them," as shown in the figure (Pl. X. fig. 13). We now know that this opening is the transverse section of the internal canal, the existence of which was first noticed by Hambach. But this author, in claiming the priority of his discovery[4], is somewhat unjust to Rofe when he says, "That the lancet-piece is perforated by a very fine canal through the centre, in its whole length, was, so far as I know, first described by me,

[1] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, p. 538.

[2] Ann. & Mag. Nat. Hist. 1882, vol. ix. pp. 215, 217, 218.

[3] Geol. Mag. 1865, vol. ii. p. 249, pl. viii. fig. 7.

[4] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, p. 537.

and not by Mr. Rofe; for he takes it to be a suture, meaning that the lancet-plate was composed of two pieces." It is quite true that Mr. Rofe imagined the lancet-plate to be composed of two pieces, but he only referred to the canal as a lozenge-shaped opening; and he certainly never imagined this to be a suture. His observations were no doubt incomplete; but in this respect they were not incorrect, as would be inferred from Hambach's account of them.

Hambach only described the canal within the lancet-plate in the typical *Pentremites*; but it was soon figured in *Granatocrinus Norwoodi* by Wachsmuth and Springer[1]. A few months later we confirmed these discoveries[2], and extended them to *Schizoblastus*, *Phænoschisma*, *Orophocrinus*, and *Codaster* (Pl. XII. figs. 9, 15, 17; Pl. XVII. figs. 1, 4–8, 12, 13; Pl. XVIII. figs. 1, 3, 4, 6); and we stated at the same time that in all these genera we had been able to demonstrate the existence of an oral ring uniting the five lancet-canals. Hambach[3] has since given a general confirmation to our results (but without mentioning them) in the following terms:—"Further investigations prove that these canals are only the radiating rays of a pentagonal ring surrounding the central orifice. In other words, the base portion of the deltoid piece is likewise perforated transversely about midways, also the little process on the interior base portion of the lancet piece, from where this canal runs downwards to the apex of the ambulacral field."

The first portion of the last sentence appears to us to contain a grave error. A perforation "about midways" in the deltoid piece must be *interradial* in its position; whereas a similar opening on the little process beneath the central end of the lancet-piece (Pl. XII. fig. 14) is exactly *radial*, and would be separated from the interradial openings in the deltoids at its sides by angles of 36°. Nevertheless Hambach describes the two openings as corresponding in position, so that the canal within the lancet-piece passes through the opening "about midways" in the deltoid and joins the oral ring. There is, however, an opening just beneath the process under the central end of the lancet-plate which is undoubtedly that to which Hambach refers; but instead of perforating a deltoid, it interrupts the suture between two deltoids, and is therefore precisely radial in position. It was figured in *Pentremites* by Wachsmuth and Springer[4], who described it as equivalent to the openings at the base of the arms in Palæocrinoids. But they were unaware that there is a canal within the lancet-plate of this genus, as was afterwards discovered by Hambach; for they imagined the under lancet-plate to be perforated. This opening was subsequently seen by ourselves in *Granatocrinus*, *Pentremites*, and *Orophocrinus* (Pl. X. fig. 15; Pl. XII. fig. 13; Pl. XV. fig. 4), and its relations were described in 1882[5]. Hambach, however,

[1] Revision of the Palæocrinoidea, Part II. pl. xix. fig. 6.

[2] Ann. & Mag. Nat. Hist. 1882, vol. ix. pp. 217–219.

[3] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, p. 538.

[4] Revision of the Palæocrinoidea, Part I. pl. iii. fig. 4.

[5] Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 218.

writing two years later[1], describes it as "nothing more than a fissure between two hydrospiric sacs for the passage of this duct[2] to facilitate a connection with the œsophageal ring underlying the *annulus centralis.*" It will be evident from all our figures that this "ambulacral opening" is in the line of the interdeltoid suture, and entirely independent of the hydrospires at the side of the under lancet-plate; for these might be removed altogether without affecting its boundaries in the least. It lies exactly beneath the central end of the canal within the lancet-piece, and is in fact the very opening which Hambach describes as perforating a deltoid "transversely about midways," and as serving for the passage of this canal to join the oral ring.

We quite believe that the canal within the lancet-piece descended through this opening beneath its central end on its way to join the oral ring. At any rate this is the inference which we should draw from the study of preparations of typical *Pentremites* like those shown on Pl. XII. figs. 15, 17, where the radial extensions of the central ring occupy the lines of suture between two deltoid pieces. Hambach agrees with us in regarding this ring as formed by the junction of canals within the lancet-plates which leave them through the little processes beneath their central ends; but he goes on to describe these *radial* canals as passing through the middle of the deltoid pieces, which would give them an *interradial* position. On the other hand, he describes this same opening between two deltoids, or, as he puts it, between two hydrospiric sacs, as serving for the passage of the duct beneath the lancet-piece on its way to join another œsophageal ring. But he gives no description of the relations of this second ring to that joining the lancet-canals, which is so easily demonstrated by grinding down a good specimen (Pl. XII. figs. 15, 17). He tells us, however, that he has obtained this second ring entire from a well-preserved specimen of *Pentremites Norwoodi.* But we should like to know on what grounds he regards the structure which he has found in *Granatocrinus* (not *Pentremites*) *Norwoodi* as the annular centre of a vessel lying *beneath* and not *within* the lancet-pieces? It may be that he changed his views since the publication of his first paper; but he nowhere gives any hint of his having done so, and in fact his second paper contains definite references to two distinct rings. So far as we can make out, however, he has not seen the two rings in any single specimen, but has obtained sections of *Pentremites* showing the ring uniting the lancet-canals (Pl. XII. figs. 15, 17); while he has found what he takes to be an altogether different structure in a well-preserved example of *Granatocrinus Norwoodi.* If the lower ring is entire in this fine specimen, some traces of the upper one should surely be visible as well. But Hambach says nothing about it, at which we are not surprised; for we have a very strong suspicion that the structure which he has seen in *Granatocrinus Norwoodi* is nothing but a cast of the ring uniting the canals *within* and not *beneath* the lancet-pieces.

[1] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, p. 538.

[2] *I. e.* the one which Hambach supposes to lie *beneath,* not *in,* the lancet-plate.

The first series of Blastoids which we received from Mr. Wachsmuth contained several specimens of *Granatocrinus Norwoodi* in the form of moulds of the interior of the calyx (Pl. VII. figs. 7–9). The boundaries of the lancet-plates and deltoids are exceedingly well shown as delicate thin ridges which radiate outward from the edge of the peristome, and soon fork, so as to enclose the central end of each lancet-plate, or rather of the bed in which it rested. Rising from each radio-deltoid suture is a kind of inverted V, which is the cast of the two hydrospire-canals that unite before they open externally by the single spiracle at the central end of each deltoid.

The original specimens from Burlington, which we received from Mr. Wachsmuth, show nothing more than this; but others, from a different locality, which have reached us subsequently, are still more perfectly preserved (Pl. VI. fig. 19). In most cases there is a delicate acicular rod lying above the middle of the somewhat linear mould of the lancet-piece. This rod is hollow in section, and enlarges very gradually towards the peristome. Just before reaching the pointed central end of this linear impression, it forks, and the two branches pass off right and left through the thin ridges that separate the impressions of the lancet-plate and of the deltoids respectively. Each branch meets a corresponding one from an adjacent ambulacrum, and so a pentagonal ring is formed which must have lain entirely within the substance of the deltoids, or if not there, immediately beneath them (Pl. VI. fig. 19); while the hydrospire-canals converging on the spiracles were altogether above it, and their casts concealed the middle points of its sides. Each of these points is slightly enlarged, and is joined by delicate rods to the corresponding points in each of the two adjacent sides. The result of this is to form a second and smaller pentagonal ring, inscribed within the one already mentioned. The sides of this inscribed pentagon are radially situated, while those of the circumscribed pentagon are interradial, and its extensions into the ambulacra proceed from its angles.

There can, we think, be no doubt whatever that the structure described above is "the circular duct (œsophageal ring?)" which Hambach has obtained entire from a well-preserved specimen of *G. Norwoodi*; but we cannot agree with him in regarding it as connecting a set of longitudinal ducts beneath the lancet-plate. In the first place, whatever may be the case in *Pentremites* proper, we have never seen any trace of the presence of a duct beneath the lancet-plate of *Granatocrinus*, of which we have probably examined a greater number of species than Hambach has. Wachsmuth and Springer[1] figure a relatively large canal within the lancet-plate, and it also appears in our own sections of the ambulacra (Pl. XVII. figs. 4–8). It is likewise to be seen as an opening in the broken end of the lancet-plate in the partially exposed cast which is represented in Pl. VII. fig. 9. In the other casts (Pl. VI. fig. 19) the whole lancet-plate is removed except the part immediately surrounding this canal; and it is

[1] Revision of the Palæocrinoidea, Part II. pl. xix. fig. 6.

distinctly above the level of the linear impression which represents the mould of the under surface of the lancet-plate. Hambach[1] gives a general description of this plate as having a longitudinal groove on its under surface; and one would therefore expect to find an impression of this groove in the mould of the under surface. It is, however, perfectly even from side to side, and entirely without any trace of the duct or vessel which Hambach mentions. We are inclined to think that his description is too general, and only applies to *Pentremites* proper, in which type the ambulacra are different from those of *Granatocrinus.* But we are certain of two points. There is no duct beneath the lancet-piece of *Granatocrinus Norwoodi*, and no other oral ring than the very complex one which unites the canals within the lancet-plates, as shown in Pl. VI. fig. 19. If this, as we have every reason to believe, was the structure which Hambach obtained entire in *Granatocrinus Norwoodi*, we are surprised that he did not think of correlating it with the canals within the lancet-plate which he described in the same paper. It will be quite time enough to think about a second oral ring connecting the longitudinal ducts beneath the lancet-pieces when the presence of these ducts shall have been satisfactorily demonstrated; but this is far from being the case at present, as pointed out above.

The complex structure of the oral ring, as preserved in *Granatocrinus Norwoodi*, is very remarkable, and has puzzled us considerably. We have seen no trace of anything of the kind in ground preparations of the summit of any Blastoid, not even in *Granatocrinus* itself; and we are also in some doubt as to the functions of this ring. But the discussion of this subject had better be postponed.

There are two different types of Blastoid in which we have found a peculiar modification of this lancet-canal. Both in *Schizoblastus Sayi* and in *Troostocrinus* (?) *lineatus* we have found the lancet-plate to contain three canals instead of one (Pl. XVII. figs. 1, 18). These are disposed at the angles of a triangle, the apex of which is downwards; so that the lower canal is just beneath the middle of the interval between the other two. We have been unable to get a satisfactory section of an ambulacrum in any other species of *Schizoblastus*; and in the section of *Troostocrinus Reinwardti*, which is shown on Pl. XVII. fig. 17, the nature of the lancet-canal is not clear at all; so that we have no opportunity of judging how far this triple perforation of the lancet-plate is a character of any generic value. At any rate it is worth notice that although so different in external form, *Troostocrinus* and *Schizoblastus* are closely allied in the structure of the spiracles.

B. The Superficial Markings of the Lancet-plate.

The median line of the upper surface of the lancet-plate is occupied by a fine groove (Pl. I. figs. 1–6, 9–11), which appears to be universally recognized as corre-

[1] Trans. St. Louis Acad. Sci. 1880, vol. iv. no. 1, pp. 149, 151.

sponding to the ambulacral or food-groove of a Crinoid, and we shall therefore speak of it by this name. The five grooves radiate outwards from the mouth just like the disc-ambulacra of a Crinoid, and we suppose that there can be little doubt of their having been ciliated during life. As in the Crinoid, too, the food-groove of a Blastoid may be covered in and thus converted into a tunnel, though the covering is but rarely preserved in the fossil state (Pl. I. fig. 8; Pl. III. figs. 2, 3; Pl. XV. figs. 11, 12). The mouth, or more strictly the peristome (for the actual mouth was doubtless membranous, as in the Urchins), is generally more or less distinctly stellate in outline, the short rays of the star being the gaps between the pointed central ends of the deltoid plates (Pl. I. figs. 4–6; Pl. III. figs. 1, 14; Pl. IV. figs. 1, 17; Pl. V. figs. 15, 19; Pl. VI. figs. 7, 8, 13; Pl. VII. figs. 5, 14, 15; Pl. IX. figs. 5, 8, 14, 15; Pl. XII. figs. 1, 4). It may be simply pentagonal (Pl. IV. fig. 14; Pl. V. fig. 2), or even round, as in *Phænoschisma nobile, P. acutum* (Pl. XI. fig. 3; Pl. XIV. fig. 11), and in *Eleutherocrinus* (Pl. XIX. fig. 6), while in some cases it is extremely constricted (Pl. IV. figs. 8, 10; Pl. V. figs. 4, 16, 23; Pl. XI. fig. 9).

In all cases alike, however, each radiating space between the proximal ends of two deltoids is continued as a slight groove on to the surface of the lancet-plate, which lies flush with the interdeltoid sutures, and is continued outwards to its distal extremity, as is well seen in *Pentremites* (Pl. I. figs. 4–6), *Cryptoblastus melo* (Pl. VII. figs. 14, 15), and *Orophocrinus* (Pl. XI. fig. 9). The proximal ends of the deltoids are usually bordered by a delicate crenulation which extends along each side of the interdeltoid suture, and then down the sides of the food-groove on the lancet-plate (Pl. IV. figs. 1, 8; Pl. VII. figs. 10, 11, 14, 15; Pl. VIII. fig. 2; Pl. IX. figs. 5, 8, 14; Pl. XIII. fig. 14).

In the broad ambulacra of a *Pentremites* such as *P. pyriformis*, with its lancet-plate completely visible, the food-groove gives off lateral branches alternately on opposite sides; and well-preserved specimens show that each of these branches, like the food-groove itself, has its double border of crenulation which extends outwards towards the edge of the lancet-plate and then gradually disappears (Pl. I. figs. 1, 2). The very extensive development of this crenulation upon the broad ambulacra of *Pentremites* seems to have led Hambach to assert that they were covered by an elastic plated integument, but his account of it will best be considered when the various forms of the side plates have been described.

In the narrow linear ambulacra of *Codaster*, *Mesoblastus*, *Granatocrinus*, and *Cryptoblastus*, however, almost the whole of the lancet-plate is concealed by the side plates which rest upon it, and the crenulation of its surface is limited to the median groove (Pl. IV. fig. 4; Pl. VII. figs. 14, 15; Pl. VIII. fig. 15; Pl. IX. fig. 16; Pl. X. figs. 8, 11, 12; Pl. XIII. fig. 14); but in other forms of *Mesoblastus*, in *Acentrotremites*, *Orophocrinus*, *Pentremitidea*, and in *Phænoschisma*, the lancet-plate is entirely concealed by the side plates, which meet one another above its median line, so that no

groove is visible on its upper surface (Pl. IV. fig. 15; Pl. V. figs. 3, 4, 19; Pl. VI. fig. 13; Pl. XI. fig. 4; Pl. XIII. fig. 19; Pl. XIV. figs. 5–7, 9, 11). This condition may likewise occur at the ends of the ambulacra in *Granatocrinus* (Pl. XI. fig. 14), *Codaster*, and apparently also in *Pentremites* and in *Cryptoschisma* (Pl. I. fig. 2; Pl. XIII. fig. 20).

C. The Side Plates.

The plates to which we have given this name are those which were designated as "Porenstücke" by Roemer in his classical monograph on *Pentremites*[1]. In this genus, and also in *Pentremitidea*, *Schizoblastus*, and *Elæacrinus*, they come into close relation with the hydrospire-pores along the margins of the ambulacra, as was first indicated by Troost[2], though not clearly so (Pl. I. figs. 1–3; Pl. III. fig. 3; Pl. IV. fig. 14; Pl. X. fig. 1; Pl. XVIII. figs. 17, 18). The same is the case in *Mesoblastus*, *Granatocrinus*, and *Cryptoblastus*, though in all these genera there is a second set of internal pores which are formed between the hydrospire-plate and the wall of the radial sinus, and are smaller than the external series (Pl. IV. fig. 4; Pl. VI. fig. 10; Pl. VII. fig. 15; Pl. VIII. figs. 15, 20; Pl. IX. fig. 16; Pl. X. figs. 11, 12). But for the presence of this internal series the external pores, which are merely gaps between the outer ends of successive side plates, would not be of much use. They are altogether absent in *Codaster*, *Phænoschisma*, *Cryptoschisma*, and *Orophocrinus* (Pl. V. figs. 23, 24; Pl. XI. figs. 4, 8, 10; Pl. XIII. figs. 14, 20; Pl. XIV. figs. 3, 6, 9, 11, 18), although side plates are present and in some cases reach a considerable relative size. In spite of these facts, however, Roemer's name ("pore-pieces") has continued in use, and may even be found in descriptions of species which are expressly stated to have no marginal pores to the ambulacra. Meek and Worthen[3] have expressed their belief that these pore-pieces are "recumbent arm-pieces similar to those of many Cystoidea," and Messrs. Wachsmuth and Springer[4] seem to share this belief. This may or may not be the case; but at any rate, it seemed to us unadvisable to be continually noticing the presence of arm-pieces in Echinodermata which are nothing if not armless. We have therefore changed the name "pore-pieces" to "side plates," and likewise prefer to substitute the word "outer" for "supplemental" in describing the supplemental pore-plates which Roemer discovered in *Pentremites* and *Elæacrinus*.

The relations of the side plates to the lancet-plate vary very greatly among the different species of Blastoids. In *Orophocrinus Orbignyanus* (Pl. XI. fig. 8), *Cryptoschisma Schulzi* (Pl. XIII. fig. 20), *Phænoschisma caryophyllatum* (Pl. XIV. fig. 3), and in all the typical *Pentremites* with more or less petaloid ambulacra (Pl. I.),

[1] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 334.

[2] Trans. Geol. Soc. Pennsylv. 1835, vol. i. pp. 226, 227.

[3] Report Geol. Survey Illinois, 1873, vol. v. p. 463.

[4] Revision of the Palæocrinoidea, Part I. 1879, p. 11.

the side plates lie against the lateral borders of the lancet-plate, but do not rest upon it so as to conceal it in any way. In all genera with linear ambulacra, on the other hand, the side plates actually rest upon the lancet-plate, which is moulded for their reception, and nothing of it is visible externally except the crenulated food-groove along its median line (Pl. IV. fig. 4; Pl. VI. fig. 10; Pl. VII. figs. 14, 15; Pl. VIII. fig. 15; Pl. IX. figs. 7, 16; Pl. X. figs. 11, 12, 17; Pl. XI. figs. 8, 11, 14, 15; Pl. XIII. fig. 14). Sometimes, indeed, there is no food-groove visible on the lancet-plate (Pl. IV. figs. 12, 15; Pl. V. figs. 3, 4, 7, 19; Pl. XI. fig. 4; Pl. XII. fig. 12; Pl. XIII. fig. 19; Pl. XIV. figs. 6, 9, 11).

The broad and more or less petaloid ambulacra of *Pentremites* are shown in Pl. I., and the relation of the side plates to the lancet-plate is also seen in Pl. XII. figs. 13, 14, and in Pl. XVI. fig. 21. The radial sinus is so wide that even the large lancet-plate is insufficient to fill it, and there is therefore a more or less extensive gap on each side of the lancet-plate which is filled up by the side plates. Each of the latter consists of two parts—a somewhat squarely cut inner end or body, which rests against the lancet-plate, and a narrower outer portion or handle. This is continuous with the distal part of the body, the proximal edge of which is cut away into a more or less marked curve. Hence, although the bodies of the side plates are in contact, the handles are not, being separated by a series of pores which lead down into the hydrospire-canal, but are partly blocked at the distal margin by the outer side plates, well shown in Pl. I. figs. 1–3. They have fallen away in the specimen represented in fig. 8, so that the pores appear unnaturally large.

In all the true Pentremites the sloping side of the radial sinus is marked by a series of transverse ridges with intervening furrows (Pl. I. figs. 6, 7; Pl. V. fig. 28). Each of the latter receives the handle of a side plate, and thus corresponds to a pore leading down into the upper part of the hydrospire-sac, the folds of which may be partially exposed, as seen in Pl. I. figs. 6 & 7, and in Pl. XII. fig. 13, or completely covered by the under lancet-plate, as shown in Pl. XII. fig. 16.

Each ambulacrum is thus traversed by two longitudinal sutural lines, which mark off the two rows of side plates from the lancet-plate between them, as is also seen in *Cryptoschisma Schulzi*, *Phænoschisma caryophyllatum*, and *Orophocrinus Orbignyanus* (Pl. I. figs. 2, 3, 5, 6, 8–10; Pl. XIII. fig. 20; Pl. XIV. figs. 3, 18; Pl. XVI. fig. 21). But these lines are sometimes almost or quite invisible (Pl. I. figs. 1, 4, 11); and as a rule they are not very distinct, except in weathered specimens (Pl. XVI. fig. 21).

Each side plate is thus wedged in between the sloping side of the radial sinus and the lancet-plate, so that its upper surface is more or less level with that of the lancet-plate against which it rests; while the sutures between successive side plates lie in faint grooves, which exactly correspond in position with the alternating lateral branches of the food-groove in the median line of the lancet-plate (Pl. I. figs. 1–3).

This seems to have led Hambach[1] to describe the whole ambulacrum as covered by a zigzag plicated integument which "was probably of an elastic texture during the lifetime of the animal. It commences at the apex of the ambulacral field, running in a zigzag from the lateral margin to the median line, so that the poral openings are always placed between two returning folds, which are flattened here to form a sort of articulating surface for the pinnulæ. It ascends in this manner, covering half of the ambulacral field to the summit of the calyx, where it surrounds in a very acute angle two of the ovarian openings, and descends in a like manner on the following ambulacral field." The last portion of this description and the figures which illustrate it, together with others published later, show that Hambach is here referring to the crenulation on the central ends of the deltoid plates which border the peristome, as shown in many of our figures of *Pentremitidea*, *Mesoblastus*, *Granatocrinus*, *Schizoblastus*, *Codaster*, &c. (Pl. IV. figs. 1, 8; Pl. VII. figs. 11, 13, 14, 15; Pl. VIII. figs. 2, 4, 9; Pl. IX. figs. 8, 14; Pl. XII. fig. 4; Pl. XIII. fig. 14). It is often more or less invisible in weathered specimens (Pl. I. figs. 4–6, 10, 11; Pl. III. fig. 14; Pl. IV. figs. 14, 17; Pl. VI. figs. 7, 13; Pl. X. figs. 8, 10; Pl. XII. fig. 1); while in *Mesoblastus crenulatus* the hollows have been sometimes worn away so much as to look almost like a row of small pits on the central end of the deltoid (Pl. VI. fig. 8). It has been already explained how this crenulation is continued outwards along the edges of the median groove on the lancet-plate, whether the latter is completely exposed, as in *Pentremites*, or partially concealed by side plates (Pl. VII. fig. 14; Pl. XIII. figs. 4, 14); and Hambach's description of the integument as running in a zigzag from the lateral margin of the ambulacrum to the median line, together with his figures illustrating it, can refer to nothing else than the crenulated lateral branches of the food-groove, which are well shown in Pl. I. figs. 1, 2, 9. In the true *Pentremites* the uncovered surface of the lancet-plate bears the inner ends of these lateral grooves, the outer ends of which coincide with the sutures between successive side plates, and have much less distinctly crenulated edges, except in forms like *P. sulcatus* (Pl. I. fig. 9). But in *Granatocrinus*, *Mesoblastus*, and other types which have the side plates resting upon the lancet-plate, the median groove of the latter has no lateral branches. It is well crenulated, as are also the inner ends of the side plates (Pl. IV. fig. 4; Pl. VIII. fig. 15; Pl. IX. figs. 7, 16), while in some species, such as *Granatocrinus Norwoodi*, more or less of the distal border is also crenulated (Pl. X. fig. 11). In those species which have the lancet-plate entirely concealed by the side plates both the inner and the distal edges of the latter may be strongly crenulated, as in *Pentremitidea* (Pl. IV. fig. 15; Pl. X. figs. 1, 3); or there may be no markings on the side plates at all, except just at their inner ends, as in some species of *Mesoblastus*, *Granatocrinus*, and *Schizoblastus* (Pl. VIII. figs. 5, 21).

[1] Trans. St. Louis Acad. Sci. 1880, vol. iv. part 1, p. 150, plate A. fig. 10.

All these markings, whether on the deltoids, side plates, or lancet-plate, are merely a delicate surface ornamentation, as was pointed out by one of us in 1881 [1]. According to Hambach [2], however, "Likewise is the zigzag plated integument preserved which covers the ambulacral field, incredible as this may seem to Mr. Carpenter, whose incredulity, however, is no evidence to the contrary. . . . . The ambulacral field which is marked ϵ in Roemer's fig. 2 on plate i. of his 'Monographie der Blastoideen' indicates the existence of a layer or integument covering the same (although not described as such)." The figure in question represents an ambulacrum which is very much in the condition of those shown in our Pl. I. figs. 10 & 11; and we cannot at all see how it indicates the existence of any covering integument. The cross markings on the ambulacrum are the lateral branches of the food-groove, which are continued outwards over the sutures between the side plates, and we quite think that Roemer was right in omitting to describe them as due to the presence of an integumentary layer. This has yet to be demonstrated by Hambach, who not only speaks of it as an actual fact, but also makes use of it for classificatory purposes [3]. Thus, for example, he places in one division "all those species in which the horizontal portion of the deltoid piece is very narrow, the sinus to both sides in the deltoid and lancet pieces comparatively large, and so surrounded by the zigzag plated integument that two of the so-formed openings appear externally only as one."

The diagram which Hambach gives in illustration of this passage is supposed to represent *Pentremites sulcatus*; but it is most remarkably different from the figure of the natural summit of this species which he gave in his previous paper [4]. Five spiracles are shown in the latter, situated very close to the peristome, from which they are only separated by the narrow rim at the central ends of the deltoids, as shown in our own figure (Pl. I. fig. 10), and also in that given by Roemer [5], who described the species originally. In Hambach's later diagram, however, not only is there a separate anal opening represented, but also ten spiracles, although, according to his description of the type, there should be only five. The two openings of each interradius are figured as separated by a portion of this elastic plated integument, a large area of which also intervenes between them and the peristome, while there is a further extension of it outwards between the spiracles and that portion of the deltoid which appears on the exterior of the calyx. We find it difficult to understand the nature of the preparation from which Hambach constructed his diagram, for his earlier figure of the "summit of *P. sulcatus*, not ground," correctly represents five spiracles close to the peristome, and just separated from one another by the crenulated food-groove while if the summit had been ground away sufficiently to show ten spiracles opening

[1] Ann. & Mag. Nat. Hist. 1881, vol. viii. p. 421.

[2] Trans. St. Louis Acad. Sci. 1884, vol. iv. part 3, p. 539.

[3] Ibid. pp. 544, 545, fig. 5.

[4] Ibid. part 1, 1880, pl. A. fig. 10.

[5] Archiv f. Naturgesch. 1851, Jahrg. xvii. Band i. Taf. iii. fig. 10 *b*.

at a distance from the peristome, as in our figures of *Pentremites Godoni* and *Elæacrinus Verneuili* (Pl. XII. fig. 17; Pl. XIX. fig. 7), the transverse striation of the lancet-plate and the crenulation of the food-groove would have been the very first things to disappear, though they are most extensively represented in Hambach's figure under the name "covering integument." Some further remarks on the arguments advanced by Hambach in favour of his assertion will be found in the 'Annals and Magazine of Natural History' for December 1881, p. 421, and April 1885, p. 279.

Besides the ordinary crenulated edging of the food-groove and its lateral branches, other markings may be detected on the ambulacra of Blastoids which are more than usually well preserved. Although partially known to Goldfuss, they seem to have altogether escaped the notice both of Roemer and of most American palæontologists, and to have been first observed by Billings in *Pentremites pyriformis*[1]. He describes them in terms which are admirably illustrated by our Pl. I. fig. 1. "The lateral branches of the food-groove do not run directly to the ambulacral pores. Each of them terminates at a point between the inner extremities of two of the pores. There is at this point a small pit, which appears to be the socket of an appendage quite distinct from that of the pinnule. The groove does not reach the socket of the pinnule, which is situated further out, between two of the pores. On the other hand, a small groove runs from each pore inward, and terminates at another socket about halfway between the pore and the main median groove of the ambulacrum. It would thus appear that, besides the ordinary pinnules, there were two other rows of appendages on each side of the median groove."

We are not sure that the inference contained in the last sentence is altogether a safe one, but we are glad to be able to confirm the general accuracy of Billings's description. The pits of the outer row which terminate the lateral branches of the food-groove are sometimes totally obscured, as seen in Pl. I. fig. 3; but in other specimens they are very evident (Pl. I. figs. 1, 2). They were described by Goldfuss[2] as a series of pores on the extremities of the transverse striæ of the ambulacra themselves. Troost denies the existence of pores in this position[3], and we have no doubt that he is right; but if the word "pits" be substituted for "pores" in Goldfuss's description it is perfectly correct. The inner row of pits was, however, unknown to him. In *Pentremites pyriformis* they are situated on the side plates at the proximal ends of the ambulacra (Pl. I. figs. 2, 3); and this is also the case in the narrow ambulacra of *Mesoblastus Sowerbyi*, *Granatocrinus ellipticus*, *G. orbicularis*, and *Phænoschisma nobile* (Pl. VIII. figs. 5, 21; Pl. IX. fig. 16; Pl. XI. fig. 4), while the second or outer row which terminate the lateral branches of the food-groove in *Pentremites* are altogether absent. This is no doubt due to the difference in the characters of

[1] American Journ. Sci. 1870, vol. l. p. 228; Ann. & Mag. Nat. Hist. 1871, vol. vii. p. 145.

[2] Petrefacta Germaniæ, 1826, Th. i. p. 160.

[3] Trans. Geol. Soc. Pennsylvania, 1835, vol. i. p. 226.

the ambulacra, the lancet-plate of *Pentremites* being completely visible, while that of *Granatocrinus* and *Mesoblastus* is more or less concealed by the side plates, and so is devoid of any lateral branches to its food-groove.

In some species of *Pentremites*, and notably in *P. sulcatus* and its allies, which have very broad and petaloid ambulacra, the superficial markings of the latter are somewhat different from those which are seen in *P. pyriformis*. This is best shown in Pl. I. fig. 9. The side plates are relatively short in the direction of the ray, but are nearly half as wide as the lancet-plate. The sutures between them are sunk in grooves which continue outwards the lateral grooves of the lancet-plate, and are very markedly crenulated. A pit is often to be seen on the suture between lancet-plate and side plate with a groove proceeding from it towards the pore, just as in some ambulacra of *P. pyriformis* (Pl. I. fig. 2). The ambulacra of *P. Burlingtonensis* and of *P. Godoni* are somewhat intermediate in character between those of *P. sulcatus* and of *P. pyriformis* respectively.

The best-preserved ambulacra which we have seen in *Codaster* have been those of *C. trilobatus*, as shown in Pl. XIII. fig. 14. The side plates are few in number, though relatively large and substantial, and they rest upon the lancet-plate without concealing its broad median groove, except in some cases at its distal end. The suture between every two side plates is interrupted by a relatively large pit, which served (we suppose) as the articulating socket for a pinnule. The same character presents itself in *Orophocrinus*, as shown in our figures (Pl. XV. figs. 7, 14). In *O. verus* we have also detected much smaller pits upon the side plates themselves with grooves proceeding from them (Pl. XIII. fig. 16), just as in the proximal parts of the ambulacra of *Pentremites pyriformis* (Pl. I. figs. 2, 3).

The ambulacra of weathered specimens sometimes acquire a very singular appearance, as in the cases of *Mesoblastus crenulatus* and *M. elongatus* (Pl. IV. fig. 2; Pl. VI. figs. 10, 11), and of *Codaster Hindei* (Pl. XII. fig. 7). From Roemer's figure[1] of a well-preserved ambulacrum in the first-named species, however, we may infer that it presents no essential difference from the characters of the more typical Blastoids; for it shows indications of the markings which have just been noticed in *Pentremites pyriformis*.

D. The Outer Side Plates.

These were discovered by Roemer[2], who designated them as "supplemental pore-plates," a name which would be an excellent one were their presence always accompanied by that of the hydrospire-pores. But the latter are often absent at the sides

[1] Archiv f. Naturgesch. 1851, Jahrg. xviii. Bd. i. Taf. iv. fig. 15 *d*.
[2] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 335.

of ambulacra on which these plates are very well developed, as in *Phænoschisma nobile*, *P. Archiaci*, and *P. Verneuili* (Pl. XI. fig. 4; Pl. XIV. figs. 6, 9). They appear to be absent, however, in *P. caryophyllatum* and in *P. acutum* (Pl. XIV. figs. 3, 11), in *Codaster* and in *Orophocrinus* (Pl. XI. fig. 8; Pl. XIII. figs. 14, 16; Pl. XV. figs. 7, 14), except perhaps in *O. Orbignyanus* (Pl. XI. fig. 10), and also in *Cryptoschisma* (Pl. V. figs. 23, 24; Pl. XIII. fig. 20), all types which are devoid of hydrospire-pores; while in *Pentremitidea*, *Granatocrinus*, *Mesoblastus*, and *Schizoblastus* they have very much the same relation to the hydrospire-pores as was described by Roemer in *Pentremites* (Pl. IV. figs. 12, 15; Pl. VIII. figs. 5, 11, 15, 21; Pl. IX. fig. 16; Pl. X. figs. 1, 3). In the latter type (Pl. I. figs. 1–3) the outer side plate rests upon the proximal edge of the handle of the side plate, so as to form the distal edge and more or less of the inner margin of the corresponding pore. The same is the case in *Mesoblastus Sowerbyi*, *Granatocrinus ellipticus*, and *G. orbicularis* (Pl. VIII. figs. 5, 21; Pl. IX. fig. 16), in all of which types the plates are relatively larger than in *Pentremites*. In *Granatocrinus campanulatus* and in *Schizoblastus Rofei*, however, the side plates are at the inner side of, rather than behind, the corresponding pores (Pl. VIII. figs. 11, 15); while in *Pentremitidea* the side plates are without a handle, and sometimes do not extend much beyond the lancet-plate on which they rest, so as to meet the sides of the sinus. The result is that both pores and outer side plates are relatively large (Pl. IV. figs. 12, 15; Pl. X. figs. 1, 3).

Notwithstanding the fact that Roemer's description of the outer side plates has been accepted and confirmed by all subsequent writers on the Blastoids, Hambach [1] has asserted that they are merely the remnants of collapsed tentacles, explaining that by this term he meant "the soft and membranaceous organs such as occupy the pores of the ambulacral field in Echinoderms." The only argument which he offered in support of this doctrine is that "the interior circumference of a poral opening is lined with a membranaceous integument." Even supposing this to be the case, we do not see how it proves that relatively large and solid structures, such as the outer side plates of *Granatocrinus orbicularis*, *Pentremitidea Lusitanica*, or *P. similis* (Pl. IV. fig. 15; Pl. IX. fig. 16; Pl. X. figs. 1, 3), are the collapsed remnants of soft and membranaceous tubes like the ambulacral tentacles of other Echinoderms; while the fact that outer side plates occur in at least three species of *Phænoschisma* (Pl. XI. fig. 4; Pl. XIV. figs. 6, 9), although the genus is entirely devoid of hydrospire-pores, is a strong objection to Hambach's theory, to which we shall refer again further on.

[1] Trans. St. Louis Acad. Sci. 1880, vol. iv. no. 1, pp. 151, 152.

E. The Pinnules.

The lateral appendages of the ambulacra of a Blastoid which are generally known as "pinnules" were discovered by Roemer[1] in the year 1848 in the genus *Pentremites*, and have since been seen in *Troostocrinus* (Pl. III. fig. 13), *Granatocrinus*, *Orophocrinus*, *Stephanocrinus*, and other types, though only in specimens from American formations. No trace of them has yet been discovered in any European Blastoid. We have nothing to add to Roemer's account of their structure, except that the arrangement of the lower joints does not appear to us to be always quite so regular as he describes. In our specimens (Pl. XI. figs. 16, 17) there may be some two or three wide basal joints before the double row commences, instead of only one as stated by Roemer; while we very much doubt whether in some of the pinnules the joints are not single throughout.

Roemer discovered the pinnules before the relations of the hydrospire-pores were properly understood, and he imagined that the pinnules were attached over the pores, which served to transmit their nutritive canals. But subsequent investigations have not confirmed this idea. Billings[2] stated distinctly that the pinnule-socket is situated between two of the pores, and Hambach[3] described it in the same way. Our own observations have led us to the same conclusion, which is the one most probable, theoretically, according to our present knowledge of the relation between the pores and the hydrospires.

Shumard[4] has described the summit of *Pentremites sulcatus* as being occasionally covered by a little pyramid which consists of about fifty pieces arranged in ten series, and Hambach[5] refers to it as made up of little tubes. We have not seen this structure in *Pentremites sulcatus*, but from the condition of the specimen figured in Pl. V. fig. 28 we should be inclined to infer that the pyramid in question is composed of the proximal pinnules immediately round the peristome, which appear to be different from those more distally placed, as is so often the case in the Crinoids.

F. The Covering Plates of the Ambulacra.

It was announced by Dr. C. A. White[6] in 1863 that the ambulacral grooves of *Orophocrinus stelliformis* are "neatly filled by a compound series of minute plates, which closely connect at the summit with five small plates" covering the peristome;

1 Neues Jahrb. f. Mineral. 1848, pp. 292–296.
2 Amer. Journ. Sci. 1870, vol. l. p. 228; Ann. & Mag. Nat. Hist. 1871, vol. vii. p. 145.
3 Trans. St. Louis Acad. Sci. 1880, vol. iv. no. 1, p. 151.
4 Ibid. 1858, vol. i. no. 2, p. 244.
5 Ibid. 1884, vol. iv. no. 3, p. 543.
6 Boston Journ. Nat. Hist. 1863, vol. vii. no. 4, p. 487.

and in the same paper he describes how the integument of microscopic plates which covers the peristome of *Granatocrinus Norwoodi* passes out between the tube-like spiracles "in a double series of plates, and was evidently continued far down the central grooves of the ambulacral fields." These observations were confirmed by Meek and Worthen [1] in 1869, and extended to *Cryptoblastus melo* and *Schizoblastus Sayi.* In all four species they found "the central opening covered by small pieces, and continuing out from these, a double series of minute alternating pieces a short distance along the mesial furrows of each pseudo-ambulacral area. . . . . These little pieces do not fill the linear furrows, however, but cover them over, so as to leave a small canal passing along under them, and under the little vault covering the central opening, in such a manner as to communicate through the latter with the visceral cavity within the body."

The first figure, showing these covering plates of the ambulacra, was that of *Orophocrinus stelliformis*, which was given by Meek and Worthen [2]. They are seen extending outwards from the peristome over the narrow proximal ends of the ambulacra, which lie between the deltoids, just as in our Pl. XV. figs. 11, 12; though to judge from the American figure the arrangement of the plates seems to be somewhat more regularly alternating than in our specimen.

Wachsmuth and Springer [3] have also given a figure illustrating the same point in *Schizoblastus Sayi.* But Hambach [4] declares that his specimens "which show a similar covering as in this last-named figure, prove that the covering consists only of fragments of broken-up pinnulæ which were washed into the ambulacral furrows and remained there." We will not venture to dispute that this may be the case in Hambach's specimens; but we should like to know the nature of the proof which satisfied him that the plates forming the covering of the ambulacra really do consist of fragments of broken-up pinnules; and even if this be the case (which we doubt) it is no argument against the existence of covering plates in other specimens which he has not seen. On Pl. III. fig. 3 we give a similar figure to that published by Wachsmuth and Springer of the summit-plates, and their extension over the proximal ends of the ambulacra in *Schizoblastus Sayi*; while the same thing is shown in *Orophocrinus stelliformis* in Pl. XV. fig. 12, and also in one ambulacrum of *Granatocrinus Norwoodi* in Pl. VII. fig. 13. We have seen other specimens of all three species which illustrate the same point; and we fully agree with White, Meek and Worthen, and with Wachsmuth and Springer that the covering is a natural one, and by no means of such an accidental character as Hambach makes out.

The regular alternating arrangement of the ambulacral covering plates is most

[1] Proc. Acad. Nat. Sci. Philad. 1869, pp. 84, 85.

[2] Report Geol. Survey Illinois, 1873, vol. v. pl. ix. fig. 5.

[3] Revision of the Palæocrinoidea, Part II. 1881, pl. xix. fig. 3.

[4] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, p. 540.

clearly seen in a large specimen of *Pentremites sulcatus* from the Chester limestone, in which the peristome is covered by a somewhat extensively developed vault (Pl. I. fig. 8). The re-entering angles of the vault correspond to the median grooves of the ambulacra, which are completely covered by a double series of alternating plates that interlock over the middle of the groove so as to close it entirely. They are much more regular in their arrangement than we have seen in any other Blastoid, and we have no hesitation in regarding them as homologous with the alternating radial dome-plates of *Cyathocrinus* and of the *Platycrinidæ*, and with the covering plates of the ambulacra in recent Crinoids. They have the same relation to the more or less regular "apical dome-plates" which cover the peristome of the Blastoids as the radial dome-plates of *Platycrinus* bear to the proximals, and the covering plates of the disc-ambulacra in the recent *Hyocrinus* or *Rhizocrinus* to the oral plates.

CHAPTER IV.

THE SUMMIT-PLATES.

THE first intimation that the summit of an ordinary Blastoid was not naturally as free as it appears to be in by far the larger number of specimens which have been obtained, was afforded by the discovery of Owen and Shumard [1] that the mouth and ovarial apertures in a specimen of *Pentremites Godoni* were "in the perfect state completely closed by a conical covering of small plates."

In the same year (1850) Roemer [2] discovered that the central opening of *Stephanocrinus* is closed by a pyramid of five pentagonal plates; though as he referred this genus to the Cystidea, his discovery, which was soon confirmed by Hall [3], attracted but little attention from students of the Blastoidea. In the next year, however, he published his celebrated description of the summit of *Elæacrinus Verneuili*, which he described as closed by six plates enclosing a hexagonal one in the centre [4]. He had seen this covering, though not in all cases the sutures between the plates, in some thirty individuals, and his general description of it has been confirmed by all subsequent writers on the genus. Among these was Shumard [5], who in 1855 concluded his diagnosis of *Pentremites Sayi* in the following terms:—"The central opening is closed by minute, usually pentagonal and hexagonal plates arranged in a manner somewhat similar to those of *Pentremites* (*Elæacrinus*) *Verneuili* (Roemer);" and he added in a note—"The same structure occurs in *Pentremites Norwoodi* and *P. melo*, Owen and Shumard, of which I have fully satisfied myself from an attentive examination of many specimens."

Hambach [6], however, has made the somewhat emphatic general statement that the central opening "was never closed by additional plates, as intimated by some authors (Billings and Shumard); although specimens are frequently found (and I have such in my collection) where it appears as if the summit were closed by additional

[1] Journ. Acad. Nat. Sci. Philad. 1850, vol. ii. pt. 1, p. 65; and Trans. St. Louis Acad. Sci. 1858, vol. i. no. 2, p. 243. We have preferred to quote the later description of this fossil which was given by Shumard, rather than the original statement by himself and Owen, in which no reference to the mouth is made.

[2] Archiv f. Naturgesch. 1850, Jahrg. xvi. Bd. i. p. 369, Taf. v. fig. 3.

[3] Palæontology of New York, 1852, vol. ii. pp. 212, 213.

[4] Archiv f. Naturgesch. 1851, Jahrg. xvii. p. 378, Taf. v. fig. 1 *e*.

[5] "Palæontology," in Swallow's First and Second Annual Report Geol. Survey Missouri, 1855, p. 186.

[6] Trans. St. Louis Acad. Sci. 1880, vol. iv. no. 1, p. 150.

plates, which on close examination, however, prove to be *Bryozoa* or ovulum-like bodies." He supported this statement in a later paper [1] by asserting that "Shumard's original specimen of *Pentremites Sayi*, which was figured by F. B. Meek, and is now in the collection of the Washington University, proves to have only a covering of minute calc-spar crystals on the summit, leavings of the surrounding matrix, which could easily be removed by applying a moist camel's-hair brush to them."

Although, of course, we have not seen Shumard's specimen, yet, thanks to Mr. Wachsmuth, we have been able to examine many examples both of *Schizoblastus* (*Pentremites*) *Sayi* (Pl. III. figs. 2, 3) and of *Granatocrinus Norwoodi* (Pl. VII. figs. 3, 4, 10–13). They both occur in the Upper Burlington Limestone, and we have not the smallest doubt that the closure of the central summit-opening is a perfectly natural condition in both species. But this causes us to have considerable doubt whether, after all, Shumard's description (with Meek's illustrative figure) of the summit-plates in *Schizoblastus Sayi* is not more accurate than Hambach's assertion that the plates in question are merely calc-spar crystals, "leavings of the surrounding matrix;" and we venture to think that it would be perfectly safe to permit Hambach to attempt their removal by applying a moist camel's-hair brush to them. Did the specimen belong to us, we should not hesitate to offer it to him for experiment.

Three years after the publication of the Missouri Report, Shumard [2] met with a specimen of *Pentremites conoideus*, which "was found to exhibit very clearly the structure represented in pl. ix. fig. 4. The central stelliform space (mouth) is perfectly closed by six small microscopic plates, a central one of a pentagonal form, surrounded by five smaller pentagonal pieces, which unite with the edges of the aperture and form a little dome." Shumard's figure certainly bears out his description. But according to Hambach [3], his original specimen "does not show anything of the remarkable structure represented in the figure;" and its appearance is simply due to the oolitic character of the rock in which it was imbedded. We cannot but think, however, that a skilled palæontologist like Dr. Shumard would scarcely have mistaken what Hambach calls "ovulum-like bodies" for more or less regular calcareous plates, such as had been previously described by Roemer in *Elæacrinus Verneuili*.

It would be very interesting to know what view Hambach takes of the summit-plates of the latter type which are represented in Pl. XVIII. fig. 16. He admits [4] that "the condition of life was undoubtedly a similar one" throughout the whole class of the Blastoidea; and as he totally denies the existence of summit-plates in *Pentremites*, he is bound to give some explanation of those described by Roemer in

[1] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, p. 540.
[2] *Ibid.* 1858, vol. i. no. 2, p. 243.
[3] *Ibid.* 1884, vol. iv. no. 3, p. 541.
[4] *Ibid.* p. 547.

Elæacrinus. But he is altogether silent upon this point, and does not venture to call the plates in question either ovulum-like bodies or Bryozoa. As regards *Pentremites conoideus,* however, he is in no doubt whatever, and is convinced that the summit-plates in Shumard's specimen are merely "ovulum-like bodies;" but to use his own expression (though with a change of names), we think that Dr. Shumard "deserves as much confidence as" Mr. Hambach, both in the case of *Pentremites conoideus* and in that of *Schizoblastus Sayi.*

It may be well to mention here that Shumard's figure was copied by Billings [1], who from his own observation of a similar example of the same species, added to it what he called "a small pore in each of the five angles of the central aperture; the five ambulacral grooves enter the interior through these pores." The latter statement is correct enough, for the pores are, so to speak, the openings of the ambulacral tunnels beneath the vault, such as are shown in our figures of *Granatocrinus Norwoodi* (Pl. VII. fig. 13) and of *Elæacrinus Verneuili* (Pl. XVIII. fig. 16). They correspond precisely, as Billings pointed out, to the ambulacral openings of the true Crinoids, and to the ambulacral, or, as he preferred to call them, the ovarian pores of *Caryocrinus.* He also applied the latter name to these pores in *Pentremites conoideus,* as he had adopted White's theory of the ova being germinated within the body, and passing out through the central aperture and down the ambulacral grooves to the pinnules. We now know, however, that this is altogether incorrect, and that the ovarian pores of Billings are merely artificial openings caused by the removal of the covering plates from the ambulacral grooves, as is well seen in Pl. I. fig. 8, Pl. III. fig. 3, and Pl. XV. fig. 12.

Some eight years after the appearance of Shumard's Missouri Report, his observations upon the closure of the summit in *Granatocrinus Norwoodi* by a group of small plates was confirmed by White [2], who described the peristome as being "overlaid with an integument of microscopic plates, entirely covering the central aperture, passing out between the bases of the tubes in a double series of plates." This is well shown in Pl. VII. figs. 4, 13, more especially in the latter figure. White further discovered essentially the same summit-structure in *Orophocrinus stelliformis* [3]. The proximal ends of the food-grooves are "neatly filled by a compound series of minute plates, which closely connect at the summit with five small plates, arranged like a five-pointed star, with the points touching each of the upper ends of the interradial plates, thus completely covering the summit-aperture, which weathered specimens show to exist beneath."

Mr. Wachsmuth has lent us an example of this species which shows these characters very well (Pl. XV. fig. 12), though the five central plates do not seem to be arranged quite as regularly as in that described by Dr. White. His observations,

[1] American Journ. Sci. 1869, vol. xlviii. p. 81, fig. 15; Ann. & Mag. Nat. Hist. 1870, vol. v. pp. 264, 265.
[2] Boston Journ. Nat. Hist. 1863, vol. vii. no. 4, p. 484.
[3] *Ibid.* p. 487.

like those of Shumard, were subsequently confirmed by Meek and Worthen, who published some excellent figures of the summit-plates of *Granatocrinus Norwoodi* and *Orophocrinus stelliformis* in the fifth volume of the 'Illinois Geological Report'[1]; and no subsequent writer, with the exception of Hambach, has ever disputed that these plates are an integral part of the organization of a Blastoid.

In his original description of the summit-plates[2], Shumard mentioned that, in addition to those covering the central opening, there were others closing the spiracles of *Pentremites*; and he subsequently[3] described each of these apertures as being closed "by six minute pentagonal plates, so arranged as to form a little elevation." We must confess to some doubt upon the latter point, never having examined a specimen which presents these characters in a sufficiently satisfactory manner; though we have certainly seen indications of what in a better state of preservation may perhaps have been a group of plates closing the spiracles. White[4], however, describes the anal aperture of *Orophocrinus stelliformis* as being completely closed by what he calls "a disk of minute polygonal plates;" while Roemer[5] and also Hall[6] described the same structure at the anal opening of *Stephanocrinus*, and there are indications of this in one of our specimens (Pl. XIX. fig. 9).

Another form of covering to the summit of *Pentremites* has been mentioned by Shumard[7] as occurring in *P. sulcatus*; but his account of it is described by Hambach[8] as "insufficient and incorrect." According to Shumard a little pyramid rises from the centre of the summit, with its salient angles interradial. "The base of this little pyramid is joined to the superior edges of the pseudo-ambulacral fields, so as to completely roof in the buccal and ovarian apertures. It consists of about fifty pieces, arranged in ten series; the first or exterior ones in each series being of a triangular form, the others elongated quadrilateral. Two series of pieces stand over each ovarial aperture, those of one side uniting with their fellows of the opposite side at the salient angles of the pyramid." The (improved) description which is given by Hambach states that this cone-shaped body "consists of little tubes running parallel with each other and roofing in the summit of the calyx in a conical shape (but not the central opening). They protrude through the same apertures in which the hydrospires terminate; there are about five of these tubes to each aperture, which seem to correspond with the plicas of the hydrospiric sac." Here Hambach's

[1] Pl. ix. figs. 2 *a*, 5.
[2] Journ. Acad. Nat. Sci. Philad. 1850, vol. ii. pt. 1, p. 65.
[3] Trans. St. Louis Acad. Sci. 1858, vol. i. no. 2, p. 243.
[4] Boston Journ. Nat. Hist. 1863, vol. vii. no. 4, p. 486.
[5] Archiv f. Naturgesch. 1850, Jahrg. xvi. Bd. i. pp. 369, Taf. v. fig. 3.
[6] Palæontology of New York, vol. ii. pp. 212, 213.
[7] Trans. St. Louis Acad. Sci. 1858, vol. i. no. 2, p. 244.
[8] *Ibid.* 1884, vol. iv. no. 3, p. 541.

observations terminate, and he proceeds to infer that these supposed tubes are the external ends of a set of ovarian tubes which are situated "below the hydrospiric sac and between the plicas." He gives us no information whatever as to how these tubes pierced the hydrospiric sac on their way to the external opening; while, as we shall point out later on, his "ovarian tubes" are merely the restricted portions of the body-cavity, which are enclosed between two adjacent lamellæ of the hydrospire-apparatus. Shumard's description may be insufficient and incorrect; but if the material at Hambach's command was perfect enough to enable him to speak in these terms of the work of his distinguished predecessor, he might surely have devoted more than five lines to a readable account of what he saw in a structure which had only been found preserved in three specimens, two of them being in his own collection.

Mr. Wachsmuth has sent us a fine specimen, which may perhaps throw some light on this difficult question (Pl. I. fig. 8). The peristome and spiracles are almost completely covered by what seems to be the base of the little pyramid described by Shumard. The upper part of this pyramid in the examples described by Shumard and Hambach seems to us to be constituted by the proximal pinnules, as in the specimen represented on Pl. V. fig. 28. In Mr. Wachsmuth's example of *P. sulcatus*, however, these proximal pinnules are not preserved, and the angles of the pyramid extend outwards towards the pointed ends of the visible parts of the deltoids. At two of these angles there seem to be indications of a double series of plates above the spiracles; while the structure is a little more irregular at two of the other angles, and somewhat more so at the remaining one, which we take to be that of the anal side. The central part of this covering is obscure, and we have been unable to make much out of it; but we have little doubt that this is fundamentally the same structure as was seen by both Shumard and Hambach. According to the latter author, there are "about five" of the supposed tubes to each spiracle; while Shumard says that two series of pieces stand over each opening, and except in the anal interradius this seems to be the condition of Mr. Wachsmuth's specimen also. But we do not think that the pieces have the tubular nature which Hambach assigns to them; for we doubt whether they are more than the proximal pinnules grouped round the peristome, as shown in our Pl. V. fig. 28. Neither do we see any reason to suppose, as Hambach does, that the tubes extend down into the interior of the calyx; for they could hardly do so without leaving some evidence of their passage through the central ends of the deltoid plates, and nothing of the kind is visible in any of the numerous specimens of *Pentremites sulcatus* which we have examined.

We are much more inclined to think that we have here to deal with an extension of the smaller system of summit-plates which occur in other Blastoids. In *Granatocrinus* and *Elæacrinus* only the peristome appears to be covered (Pl. VII. figs. 4, 11, 13; Pl. XVIII. fig. 16), except perhaps for the anal plate in *Granatocrinus Norwoodi*; while *Orophocrinus* and *Stephanocrinus* have a group of plates around the anal

aperture (Pl. XIX. fig. 9). In *Pentremites conoideus* the other four spiracles are perhaps also closed by plates; and except in the larger size and abundance of the plates it is no great advance from this condition to that which we have seen in *Pentremites sulcatus* (Pl. I. fig. 8), but we await further information.

For some little time after the discovery of the summit-plates of the Blastoids, no special attention was paid to their morphological importance. It was natural enough to compare them, as some authors did, to the vault of the Actinocrinidæ; but no detailed comparisons were made until, in 1877, Wachsmuth[1] pointed out that a definite arrangement of plates is more or less traceable in the vault of many Palæocrinoids. There is a single central plate, with five or, more frequently, six others disposed interradially round it. Four of these six are of tolerably equal size, while the other two are smaller and situated in the anal interradius, being separated from each other by the anal plate or by the proboscis. Wachsmuth has described these seven pieces as the "apical dome-plates," and finds that they are represented in the vault of most, if not all, Palæocrinoids. They are relatively larger in young individuals, and in older specimens are sometimes altogether indistinguishable from the other plates of the vault, which are developed outside them. But Mr. Wachsmuth's researches leave little doubt that they are present, at any rate in early life, in all the more typical forms of Actinocrinidæ, Platycrinidæ, and their allies, which he groups together provisionally under the name of Sphæroidocrinidæ.

He further points out that these apical dome-plates "surmount the vault of *Symbathocrinus* and *Cyathocrinus*, cover the central opening of the Blastoids, and can be traced in many of the Cystideans." He also suggested that "the centre piece corresponds evidently with the basals of the dorsal side, the surrounding plates to the subradials (the two smaller plates, separated by the anus, forming together one large one)." In the more rational nomenclature which is now in almost general use for the calyx of a Crinoid, the centre piece would be compared to the under-basals, and the proximal dome-plates to the basals. In 1879 Dr. P. H. Carpenter[2] suggested that, as the under-basals are somewhat variable elements in the calyx of a Crinoid, it would be better to substitute for them the central plate of the abactinal system of an Echinoderm, or "dorsocentral," as the homologue of the central dome-plate, which he subsequently proposed to call the "orocentral"[3]. We understand that Mr. Wachsmuth has now abandoned his original view that the proximal dome-plates are homologous with the basals of the abactinal side. But it is has always appeared to us that this was a peculiarly fortunate suggestion, and one which threw a flood of light upon the structure of the summit in all the Crinoidea. For it has been shown by

[1] Amer. Journ. Sci. 1877, vol. xiv. pp. 186–189.

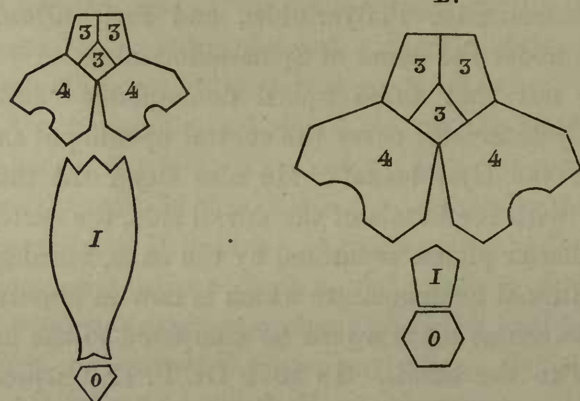
[2] "On the Apical and Oral Systems of the Echinodermata," Part II., Quart. Journ. Micr. Sci. 1879, vol. xix. pp. 181, 182.

[3] Zool. Chall. Exp. part xxxii. 1884, p. 169.

Goette[1] that the oral plates of a Neocrinoid are truly homologous with the basals, being developed spirally round the left peritoneal sac, while the basals appear in a similar spiral round the right peritoneal sac; and from the year 1879 onward, the homology of the proximal dome-plates with the orals of a Neocrinoid has been steadily insisted on by one of us.

The simplest form of vault which occurs among the Palæocrinoids is that presented by the young stages of *Allagecrinus*. We have examined a large series of specimens of this type, but have never been able to make out that the vault consists of anything more than the five plates which we have described as orals[2]. In *Haplocrinus* the apex of the vault is capped by an orocentral, which reaches a relatively larger size in *Symbathocrinus*. Neither *Allagecrinus* nor *Haplocrinus* has any calyx-interradials, and the oral pyramid, as we regard it, rests directly upon the radials. In *Culicocrinus*, however, the five large plates which form the vault rest on the calyx-interradials, the posterior one being rather the larger, with its distal margin excavated for the anal opening. In this type the orocentral seems to be absent, as in *Allagecrinus*; but in *Platycrinus* there is rather more complexity of structure. Besides the orocentral and the proximals, there are some other plates in the vault which

A. Fig. VI. B.



Diagrams to illustrate the relation of the summit-plates to the interradials of the abactinal system.

A. *Elæacrinus elegans* (modified from Hall). B. *Platycriuus,* sp. 3. Basals. 4. Radials. *I.* Interradials. *O.* Proximal summit-plates (Orals).

bound the ambulacral openings, and the posterior proximal seems to be represented by two plates which are separated by the anal tube. In the simplest form of *Platycrinus* the proximals rest directly on the primary interradials of the calyx (Fig. VI. B). But in other species, and in the Actinocrinidæ, the structure of the

[1] "Vergleichende Entwickelungsgeschichte der Comatula Mediterranea." Archiv f. Mikroskop. Anat. 1876, Bd. xii. pp. 595, 621.

[2] "On *Allagecrinus*, the Representative of a new Family from the Carboniferous Limestone Series of Scotland." Ann. & Mag. Nat. Hist. 1881, vol. vii. pp. 285–287.

vault becomes much more complex, though the orocentral and the proximals (orals, as we regard them) can generally be made out. According to Wachsmuth and Springer[1], "they are generally larger than the other dome-plates, and more prominent, frequently nodose or spiniferous, though in some species they cannot, at least in mature specimens, be readily distinguished from the other dome-plates which have attained equal size."

Among the Blastoids we have a similar, though far less extensive, series of variations to that which can be traced among the Palæocrinoids. The simplest form of summit which occurs in any Blastoid is that presented by *Stephanocrinus*. The peristome is completely closed by the five triangular plates of the so-called proboscis, which are less distinct in our specimen (Pl. XIX. fig. 9) than in that figured by Roemer[2]. Their bases rest against the interradial pieces or deltoids, and they are thus in the same relative position as the large and tubercular proximals of the simple *Platycrinus* (Fig. VI. B) or of *Culicocrinus*, and, as in the latter type, there is no orocentral. But the posterior oral does not appear to be any larger than its fellows, as is the case in *Culicocrinus*. This is perhaps due to the position of the anus, which is situated some way from the peristome upon the posterior coronal process (Pl. XIX. figs. 8–10). It may be noted here that in Hall's diagnosis of *Elæacrinus* (*Nucleocrinus*) he says "the summit occupied by five or more plates," but that he only figures five, of equal size, however, in his diagram of the structure of the summit in *Elæacrinus elegans*[3]. These five plates of *Stephanocrinus* and *Elæacrinus* have exactly the same relation to the peristome and ambulacra as the oral plates of a Neocrinoid, and we do not see how their mutual homology can well be disputed.

Since the preceding paragraph was in type we have received the latest publication of Messrs. Wachsmuth and Springer, according to whom the five plates which form the ventral pyramid of *Stephanocrinus* are "calyx interradials," and cannot therefore be homologous with the orals of a Neocrinoid[4]. In making this comparison Messrs. Wachsmuth and Springer seem to have altogether overlooked the fact that *Stephanocrinus* has well-developed calyx-interradials, namely, the deltoids (Pl. XIX. figs. 8–12). This was explained by us in 1883[5], and it is referred to again on page 34 of our present work.

The American authors regard the deltoid pieces of the Blastoidea, and by implication therefore those of *Stephanocrinus*, as homologous with the large calyx-interradials of the Cyathocrinidæ, a view in which we entirely concur, as we have explained

[1] 'Revision of the Palæocrinoidea,' Part II. p. 16.
[2] Archiv f. Naturgesch. 1850, Jahrg. xvi. Bd. i. Taf. v. fig. 3.
[3] Fifteenth Ann. Report, New York State Cabinet Nat. Hist. 1862, pp. 146, 153.
[4] 'Revision of the Palæocrinoidea,' Part III. Proc. Acad. Nat. Sci. Philad. 1885, p. 268 (46).
[5] Ann. & Mag. Nat. Hist. 1883, vol. xi. p. 239.

on page 10. But in applying this name to the five plates which form the ventral pyramid and cover the mouth of *Stephanocrinus*, and also of *Haplocrinus* and *Allagecrinus*, as they do in their latest publication, they seem to us to be going very much too far. We regard the five summit-plates of all three genera as truly homologous with the orals of the Pentacrinoid larva. They cover the mouth and the origin of the ambulacra, just as the orals do in the Neocrinoid; and this relation is not characteristic of the calyx-interradials in any Pelmatozoon whatever. It is only in the Cyathocrinidæ and in the Blastoids that these plates have any close relation to the mouth at all. But they do not cover it and shut it off completely from the exterior, as they summit-plates of *Stephanocrinus* and *Allagecrinus* do. For they form the circumference of the peristome, from which the ambulacra pass outwards over their apposed lateral edges (Pl. I. fig. 5; Pl. III. fig. 14; Pl. IV. figs. 1, 14; Pl. VII. fig. 14). There is not a single Crinoid known in which plates that are universally recognized as calyx-interradials cover in the *actinal* centre. The very name "calyx-interradials" implies plates that are *abactinal* in their origin; while in Crinoids, Blastoids, and Cystids alike we meet with types such as *Allagecrinus*, *Stephanocrinus*, and *Glyptosphærites*, in which the mouth is covered by a pyramid of five closely fitting plates just as in Neocrinoids (*Hyocrinus*), Urchins (*Palæostoma*), and Holothurians (*Psolus*). There are therefore very strong reasons for regarding all these plates, which have the same relations in five different classes of Echinoderms, as mutually homologous, *i. e.* as oral plates[1]. One would like to know whether Messrs. Wachsmuth and Springer are prepared to call the five plates which cover the mouth of *Glyptosphærites* "calyx-interradials," and if so, where the radials are on which they rest.

The difference between *Elæacrinus elegans* or *Stephanocrinus* and *E. Verneuili*, as described by Roemer, is very much the same as that between *Culicocrinus* and the simplest form of *Platycrinus*. *Stephanocrinus*, like *Culicocrinus*, has but five plates in the vault; while in *Elæacrinus Verneuili* there are at least seven, viz. an orocentral, four proximals of equal size, and two smaller ones on the anal side. This is the construction of the summit in the specimen figured by Roemer[2], while in the best preserved one which we have seen there is an additional plate in the proximal row and one or two distal plates as well (Pl. XVIII. fig. 16). According to White[3] the summit of *Orophocrinus stelliformis* consists of "five small plates, arranged like a five-pointed star, with the points touching each of the upper ends of the interradial plates," just as in *Stephanocrinus* and in *Elæacrinus elegans* (Fig. VI. A.). This arrangement does not seem to be very constant, however, as it can scarcely be traced either in Meek and Worthen's figure[4] or in the individual represented in our Pl. XV. fig. 12.

[1] See on this subject, Quart. Journ. Micr. Sci. 1879, vol. xix. pp. 191, 192.
[2] Archiv f. Naturgesch. 1851, Bd. i. Taf. v. fig. 1 *e*.
[3] Boston Journ. Nat. Hist. 1863, vol. vii. no. 4, p. 487.
[4] Report Geol. Survey Illinois, 1873, vol. v. pl. ix. fig. 5.

The summit of *Granatocrinus Norwoodi* seems to vary in a similar manner. The individuals figured in Pl. VII. figs. 4, 13, show traces of proximals arranged around an orocentral; whereas in other cases no great regularity is visible in the grouping of the summit-plates (Pl. VII. fig. 11).

It sometimes happens that impressions of the summit-plates appear in internal casts, as shown in that represented in Pl. VI. fig. 20, in which the impressions of the orocentral and of the four anterior proximals are tolerably distinct. A somewhat less regular arrangement appears in the case of *Schizoblastus Sayi*, which we figure on Pl. VI. fig. 18 ; and Shumard [1] described the summit-plates of his specimens as being arranged in a manner somewhat similar to those of Roemer's *Elæacrinus Verneuili*; but in other specimens of this type it is difficult to distinguish the orocentral and proximals among the number of other plates in the summit. We have no question, however, that these are perfectly natural in character, and not, as Hambach [2] asserts, either fragments of matrix, Bryozoa, or any other foreign bodies.

[1] Palæontology, Swallow's 1st and 2nd Annual Report Geol. Survey Missouri, 1855, pt. 2, p. 186.

[2] Trans. St. Louis Acad. Sci. 1880, vol. iv. no. 1, p. 150.

CHAPTER V.

THE HYDROSPIRES AND SPIRACLES.

A. Historical.

The name "Hydrospires" was given by Billings [1] in 1869 to the remarkable system of lamellar tubes which lie between, and more or less beneath, the ambulacra of a Blastoid. In the Codasteridæ they open externally on the ventral aspect of the calyx by a series of elongated slits in the interradial areas which lie nearly parallel to the ambulacra (Pl. XIII., XIV.); while in the Pentremitidæ they are entirely concealed beneath the ambulacra, and are only exposed after removal of the lancet-plate and side plates (Pl. I. figs. 6, 7; Pl. XII. fig. 13).

The first author who seems to have taken any special notice of the hydrospire-slits was Troost [2], who gives a figure of a "Pentremites, the ambulacrum being removed, showing the ridges and furrows," while he speaks of the "interior" of the ambulacrum as being "longitudinally furrowed, forming a number of channels which fit in similar channels of the interior of the body."

The next reference to these organs with which we are acquainted occurs in the description of *Codaster* by Professor McCoy [3], who noticed that four of the interradial areas of the summit "are marked with coarse, rough, parallel striæ nearly coinciding in direction with the pseudambulacral ridges, and converging to the second set of ridges; the impressed lines between these striæ *seem* punctured, the fifth (? posterior) space is without sulcation." He was unable, however, to make any suggestion as to the nature of this sulcation. A few years later Roemer [4] described for the first time the lamellar tubes which lie beneath the ambulacra of *Pentremites*, and their communication with the exterior through the summit-openings, to which the name "spiracles" was afterwards given by Billings. But the relation between

[1] American Journ. Sci. 1869, vol. xlviii. p. 75: Ann. & Mag. Nat. Hist. 1869, vol. v. p. 258.

[2] "On the *Pentremites Reinwardtii*, a new fossil; with remarks on the genus *Pentremites* (Say), and its geognostic position in the States of Tennessee, Alabama, and Kentucky," Trans. Geol. Soc. Penn. 1835, vol. i. p. 227, pl. x. fig. 7.

[3] Ann. & Mag. Nat. Hist. 1849, vol. iii. p. 250.

[4] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. pp. 339–341.

the tubes and the marginal pores of the ambulacra escaped his notice; though he pointed out that the tubes seemed to obstruct the communication of these pores with the internal cavity of the calyx, a communication which he believed to exist on theoretical grounds as he supposed the pores to represent the nutritive canals of the so-called pinnules.

Roemer also described the ridges and furrows (or hydrospire-slits) on the ventral surface of *Codaster* (Pl. XIII.), and he rightly compared them to the slits which appear at the sides of the ambulacra in *Phænoschisma caryophyllatum* [1] (=*Pentremites Orbignyanus*, Roemer (*non* de Koninck) (Pl. XIV. figs. 1–4)). But as he made no sections of the calyx in either of these two types, the identity of their hydrospire-slits with the tubular apparatus concealed beneath the ambulacra of a true *Pentremites* altogether escaped his notice. New species of *Codaster* were described a few years later by both Lyon and Shumard; but they added nothing to our knowledge of the morphology of the hydrospires. McCoy [2], however, had recognized in 1849 the resemblance of the hydrospire-slits of *Codaster* to the pectinated rhombs of the Cystids, and the same remark was made by Hall [3] in 1861.

In the course of the following year two suggestions of very different character were made as to the nature of the hydrospires and of their external openings, the so-called "spiracles." It appeared to White [4] that the prevailing view of the summit-openings as ovarian apertures was not consistent with our knowledge of the mode of deposit and dispersion of the ova of the closely allied Crinoids. He thought it probable that they were the "apertures of siphonal tubes for the vibration of the tentacula, by the injection and expulsion of water; communicating by way of the tubular apparatus beneath each ambulacral field with each tentacle through the pores, expanding them by the inflation of the tubular canal along their inner grooves, and contracting them by the expulsion of the water. It is conceived that this operation of the siphonal tubes would produce all the necessary motion of the tentacula, and be more in accordance with the status of the animal than a complex muscular system which would otherwise be necessary to operate the hundreds of these minute organs."

Ingenious as this theory is, it is totally inconsistent with our knowledge of the recent Crinoids. It requires a strong effort of the imagination to conceive that

[1] The hydrospire-slits are incorrectly represented in Roemer's figure of this species. They are shown as having their proximal ends exposed, and their distal ends concealed beneath the ambulacra; whereas in reality the reverse is the case, as shown in the side view of the calyx which is given by Roemer and in our own figures, Pl. XIV. figs. 3, 4.

[2] Ann. & Mag. Nat. Hist. 1849, vol. iii. p. 251.

[3] "Descriptions of new species of Crinoidea from the Carboniferous Rocks of the Mississippi Valley," Journ. Bost. Soc. Nat. Hist. 1861, vol. vii. no. 2, p. 327.

[4] *Ibid.* 1863, vol. vii. no. 4, p. 485.

there was an injecting apparatus beneath each ambulacrum of a Blastoid capable of moving fifty pairs of pinnules, each composed of a more or less double row of calcareous joints. On the other hand, some recent Crinoids have over one hundred arms, each composed of 100–150 joints, with a pinnule on every one. With a few exceptions, every arm-joint and every pinnule-joint is united to those before and behind it by a pair of muscular bundles. Is not this a muscular system vastly more complex than any Blastoid could have ever possessed?

This theory of White's has not met with any acceptance among naturalists for the reason already mentioned. It has never been seriously discussed, and has gradually passed into oblivion, so that there is no need to refer to it any further.

The case is different, however, with Messrs. Dujardin and Hupé [1], whose remarks on the hydrospires, although short, are very much to the point. They were the first to recognize that the interambulacral hydrospire-slits of *Codaster* lead into lamellar tubes resembling those which lie beneath the ambulacra of *Pentremites*; and like both McCoy and Hall they compared this system to the pectinated rhombs of the Cystids, which were then gradually coming to be regarded as respiratory in function. "Ces lames, ou ces canaux lamellaires, quand ils sont tout-à-fait internes, reçoivent le liquide extérieur par les pores des ambulacres, et l'on peut penser que le double orifice qui termine chaque ambulacre vers le centre des Pentrémites, est destiné à la sortie de l'eau qui a servi à la respiration." We are strongly inclined to think that the view taken by Dujardin and Hupé concerning the relation between the hydrospire-pores and the summit-openings is the true one, the former being afferent, and the latter efferent; and for this reason we think it all the more likely that the summit-openings also served for the discharge of the genital products as supposed by Say, Roemer, and others. Dujardin and Hupé, however, not only abandoned this view as improbable and incorrect, but they attributed a genital function to the lateral opening which had been generally described as the anus [2], and was supposed to be oro-anal by White. In this step we cannot follow them, but they are certainly entitled to the credit of being, so far as we know, the first writers to give a rational explanation of the function of the hydrospires as respiratory organs.

Their remarks appear to have been unknown to Rofe [3], who obtained vertical sections of the hydrospires in *Pentremites*, *Granatocrinus*, and *Codaster*, and was the first to demonstrate the connection of the pores at the sides of the ambulacra with the tubular apparatus beneath them; but the absence of these pores in the last named genus seems to have puzzled him. His sections, however, enabled him to

[1] Hist. Nat. des Zoophytes Échinodermes, Paris, 1862, p. 88.

[2] *Ibid.* pp. 88, 89.

[3] Geol. Mag. 1865, pp. 249–251.

verify the suggestions of McCoy and Hall respecting the close similarity between the hydrospires of *Codaster* and the pectinated rhombs of a Cystid; and he suggested "the possibility of their being respiratory sacs, lined with cilia, and constructed of a porous test, through which air from the water could pass by diffusion." Meek and Worthen[1] writing in 1869 doubted the respiratory nature of the hydrospires because of the absence of any direct communication between their cavities and the general body cavity in which they are suspended. The American palæontologists also pointed out that "it appears more in accordance with all that is now known in regard to the general anatomical structure, and the arrangement of the reproductive organs of the living types of the Crinoidea, to suppose that the opening usually regarded as the anus in the Blastoids was really such, or, as Dr. White and Mr. Billings maintain, both mouth and vent, than that it was an ovarian aperture." Meek and Worthen also express their agreement with Dr. White and others "who reject the opinion that any of the other openings in these fossils were ovarian apertures." They did not, however, offer any positive suggestion with regard to the nature of the hydrospires or of the peripheral summit-openings. Billings[2] writing in the same year expressed himself as convinced that the pectinated rhombs of the Cystids are respiratory organs. "In all the species in which they occur they seem to be constructed on the same general plan, *i.e.* the interposition of an exceedingly thin partition between the circumambient water and the fluid within the general cavity of the body." Billings confirmed Rofe's account of the identity in structure between the hydrospires of the Cystids and those of *Codaster*; and he further showed[3] that the various forms then referred to *Pentremites* "exhibit a gradual passage, from those with the hydrospires almost entirely exposed, through others, in which they are crowded more and more under the arms, until at length they become altogether internal." He described the hydrospire of *Pentremites* proper[4] as "an elongated internal sac, one side of which is attached to the inside of the shell, while the side opposite, or toward the central axis of the visceral cavity, is more or less deeply folded longitudinally . . . . . The object of the folding is, of course, to confine this large amount of surface to a small space . . . . . an arrangement which at once proves the function to be respiratory." He also pointed out[5] that *Pentremites* has ten hydrospires connected together in pairs, each pair communicating with the exterior by a single interradial opening which he proposed to call a spiracle.

Billings further endeavoured "to show the gradual passage or conversion of the respiratory organs of the Cystidea, Blastoidea, and Palæocrinoidea into the ambulacral

[1] Proc. Acad. Nat. Sci. Philad. 1869, p. 85.

[2] American Journ. Sci. 1869, vol. xlviii. pp. 75, 76; Ann. & Mag. Nat. Hist. 1870, vol. v. p. 257.

[3] *Ibid.* p. 79; *id.* p. 261.

[4] *Ibid.* p. 80; *id.* p. 263.

[5] *Ibid.* 1870, vol. xlix. p. 54; *id.* 412.

canal-system of the recent Echinoderms, and that as the convoluted plates of the former have the same structure and connections as the madreporic sacs and tubes or sand-canals of the latter, they are most probably all the homologues of each other." He pointed out first of all the resemblance between *Codaster* and *Caryocrinus*, each with its five groups of hydrospires on the summit[1]; and he continued :—"In *Pentremites*, as in *Codaster*, the five hydrospires are divided into ten equal parts by the five rays. In *Codaster* these ten parts remain entirely separate from each other; but in *Pentremites* they are reunited in pairs, the two in each interradial space being so connected at their inner angles that their internal cavities open out to the exterior through a single orifice or spiracle." He also described how the hydrospires of *Pentremites* (*Granatocrinus*) *ellipticus* "instead of being formed of broad sacs with a number of folds on one side, consist of ten simple cylindrical tubes connected together in five pairs."

As he believed *Codaster* to be a Cystid, he was able to say that "between the Cystidea and the Blastoidea the most important changes are that in the latter the hydrospires become connected in pairs, and are also brought into direct communication with the pinnulæ. In the palæozoic Crinoidea (or at least in many of them) concentration is carried one step further forward, the five pairs of hydrospires being here all connected together in the centre." It was at this stage of his demonstration that Billings made a serious mistake. He had distinctly described the hydrospires as grouped into ten interradial pairs, each with its summit-opening between the origins of two ambulacra. But his next step was to suppose that the two hydrospire tubes at the sides of each ambulacrum of a Blastoid became united in the Crinoid into a single tube, situated beneath the ambulacrum, and therefore radial in position, namely, the radial water-vascular trunk. The five ambulacral canals thus formed were supposed by Billings to be attached, not to an œsophageal ring, but to the upper extremity of the convoluted plate, which he regarded as representing the sand-canal of a Starfish. Subsequent researches have shown, however, that this latter view is altogether untenable; while the supposed concentration of the ten interradial hydrospires of *Granatocrinus ellipticus* into the five radial water-vessels of a Crinoid is at variance with every principle of Echinoderm morphology. Not only is there every reason to believe that the Blastoids possessed ambulacral vessels which were united into a ring round the mouth, but also representatives of the hydrospire-sacs of the Blastoids are to be found in recent Echinoderms (Ophiurids) as pointed out by Ludwig[2].

[1] Billings remarked that two of these groups are incomplete in *Codaster*, in order to make room for an opening which he called "the large mouth and vent." It would have been more correct if he had grouped the hydrospires into interradial pairs instead of into radial ones (p. 412), and had simply said that one pair was altogether absent (Pl. X. fig. 19; Pl. XII. figs. 1, 4; Pl. XIII. figs. 1, 4).

[2] 'Morphologische Studien an Echinodermen,' Leipzig, 1877, p. 282.

Except for this suggestion, no contributions were made to the morphology of the hydrospires for more than ten years after Billings wrote. But their respiratory function was generally recognized, and Billings's names "hydrospires" and "spiracles" were adopted as convenient and expressive.

The Canadian author seems to have altogether abandoned the theories of Say and his successors as to the genital function of the peripheral summit-openings. Most writers were inclined to compare them to the genital openings in the apical system of *Echinus*, which are dorsal in position, while those of the Blastoids are ventral. Edward Forbes[1] remarked, however, that they correspond very closely in position with the genital openings of a Starfish, and more especially with those of Ophiurids[2].

Forbes supposed that one pair of the ovarian pores was suppressed in consequence of the anal pore being brought near to the mouth, whereas in the Starfish it remains on the dorsal surface. Roemer[3] pointed out, however, that the fifth pair is present in *Pentremites*, but concealed within the large anal opening; and he further stated that in consequence of the manner in which the hydrospire-apparatus opens externally by the spiracles it must be regarded as "Behälter der Eierstöcke und Eileiter." But he remarked that in this case the Blastoids would differ very much from the Crinoids, for Müller's observations had shown that the genital glands of *Pentacrinus* and *Comatula* are situated in the pinnules. White[4] followed this up by saying that if the tubular openings of *Pentremites* "are to be regarded as ovarian apertures, it will be necessary, as before remarked, to disregard the close analogy of these animals with the true Crinoids, in which the ova are developed in little accessory sacs at the base of each tentacle, between which organs and the summit tubes of this species[5] there is no connection and apparently no indication that any ever existed. It seems more probable that as the ova were germinated within the body they found their exit through the central summit aperture, and were conveyed along the small central grooves of the pseudambulacral fields, before mentioned, to the bases of the tentacula, where they were developed and discharged as in the true Crinoids." White's theory was based essentially upon the fact that the central opening of the summit could not be the mouth, owing to its being covered up by the small plates of the vault, and he was therefore led to regard it as ovarian in function. There can be no doubt, however, that the central opening was the mouth, and that the ambulacral grooves were lined by cilia, all working towards it; so that the currents of water converging on

[1] "On the Cystideæ of the Silurian Rocks of the British Islands," Mem. Geol. Survey Great Britain, 1848, vol. ii. part ii. p. 529.

[2] The *Pentremites pentagonalis* employed by Forbes in this comparison seems to have been a *Codaster* or *Phænoschisma*, which have no genital openings at all; though he was led to insert them into his diagram from his knowledge of their presence in the true *Pentremites*.

[3] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 344.

[4] Journ. Bost. Soc. Nat. Hist. 1863, vol. vii. no. 4, p. 485.

[5] *Granatocrinus Norwoodi*.

the mouth would have effectually prevented the passage of immature ova along the ambulacra in the opposite direction, as suggested by White. Knowing that the ova of a Crinoid are developed in the pinnules, and believing these appendages to be represented by the so-called pinnules of a Blastoid, he was driven to suppose that although the ovaries of a Blastoid might be within the body, the ova after germinating found their way to the bases of the pinnules, where they could be developed and discharged. In the Crinoids, however, the actual ovaries are situated in the pinnules and are much more than the little accessory sacs described by White.

White's views have found favour with no one but Billings [1], who described himself as being in perfect agreement with them. "The central aperture is not the mouth; in fact it is not a natural orifice, but a breach in the summit caused by the destruction of a portion of the vault;" and he went on to say that the true natural orifices are the minute pores at the edge of the covered peristome where the ambulacra pass under the vault. It may be noted, however, that these pores do not exist in specimens which have the covering plates preserved on the ambulacra (Pl. I. fig. 8). Billings believed the median grooves of the ambulacra to have been exclusively occupied by the ovarian tubes, so that "then the arm of *Pentremites* would have the respiratory portion of the ambulacral system on its dorsal, and the ovarian portion on its ventral aspect. In the true Crinoids, both the respiratory and ovarian tubes are situated in the groove in the ventral side of the arm [2]."

We have pointed out above, however, that the hydrospires can in no way be regarded as a respiratory portion of the ambulacral system; while the analogy of recent Crinoids goes to show that the ambulacral groove of the Blastoids was a ciliated food-groove, and that it was not occupied by any portion of the generative apparatus, as supposed by Billings, whose theories as to the position of the mouth and generative apparatus in the Palæocrinoids and Blastoids were the result of a total misapprehension of the anatomy and physiology of recent Crinoids. He often confounded the arm-groove on the ventral surface of the skeleton with the ambulacral groove on the ventral surface of the arm, which is separated from the arm-groove by the nervous, vascular, and generative trunks, and by two radiating extensions of the body cavity. Much of Billings's reasoning upon the Palæocrinoids and Blastoids depends on the erroneous supposition that all these organs were situated in the ambulacral groove, whereas in reality they are all below it. Had he properly understood this fact, he could never have supposed that the ambulacral groove of a Blastoid is so completely filled up by an ovarian tube that almost no room remained for currents of water conveying food to the central opening, which he refused to regard as a mouth on account of its being closed by a vault.

[1] American Journ. Sci. 1869, vol. xlviii. p. 83; Ann. & Mag. Nat. Hist. 1870, vol. v. p. 265.

[2] *Ibid.* 1870, vol. l. p. 227; *id.* 1871, vol. vii. p. 144.

Meek and Worthen[1], writing about the same time as Billings, found that the pinnules of *Pentremites* "are each composed of a double series of alternately arranged pieces and provided with a distinct longitudinal furrow along the inner side, exactly corresponding to the ambulacral furrows in the arms and pinnulæ of the typical Crinoids. It is therefore probable, as suggested by Dr. White, that these furrows, in at least a portion of the pinnulæ, were provided with receptacles for the ova as in the true Crinoids." But the American authors do not commit themselves as to the position of the genital glands in *Pentremites*.

We do not believe for a moment that the pinnules merely contained receptacles for ova which travelled down the ambulacra from the summit in order to mature within the pinnules in the manner suggested by White; but, on the other hand, we see no very great improbability in the supposition that the ovaries themselves were situated in the pinnules. There are, however, one or two points which seem to us to tell against this view. In the first place we much doubt whether the pinnules of Blastoids can be regarded as homologous with those of a Crinoid. The latter are repetitions of the arms on a small scale, with the same nervous, vascular, and generative trunks, which last enlarge to form the fertile portions of the genital glands. They receive branches of the ambulacral or food-grooves, and thus form an essential part of the apparatus for collecting the food particles in the water and sending them down towards the mouth. But we doubt if there can have been anything of this kind in the Blastoids, and there were certainly no lateral branches from the water-vascular trunk within the lancet-plate into the pinnules. Furthermore the apparently isolated ovaries of a Crinoid are in reality only the specially developed and fertile portions of an extremely extensive genital gland, which has its centre in the disc and sends ramifications along each arm beneath its ambulacral groove. We see no reason to believe that there was anything of this kind beneath the ambulacra of a Blastoid where so much room is occupied by the lancet-plate and the hydrospire-sacs; while it is difficult to see how such a subambulacral genital rachis could have given off branches into the cavities of the pinnules which are situated more or less above the ambulacrum.

Among the recent Echinoderms it is the Ophiurids rather than the Crinoids which appear to present structures corresponding to the hydrospire-sacs of a Blastoid. Studer[2] showed in 1876 that the genital slits of Ophiurids lead into oval pouches which lie at the sides of the arm-bases and have their walls strengthened by limestone rods. The ovaries open into these pouches, which frequently contain young Ophiurids undergoing a direct development. Studer therefore spoke of them as

[1] Proc. Acad. Nat. Sci. Philad. April 1869, p. 86.

[2] "Über Echinodermen aus dem antarktischen Meere und zwei neue Seeigel von den Papua-Inseln, gesammelt auf der Reise S.M.S. Gazelle um die Erde." Berlin Monatsber. 1876, p. 462.

marsupial pouches; while Ludwig [1], to whom Studer's observations were unknown, named them genital bursæ, in consequence of their relation to the apparently isolated genital tubes which he found to be in reality the fertile portions of an extensively ramifying genital gland enclosed within a blood sinus, just as in the Crinoids. These genital organs are always situated "mit ganz kurzen Ausführungsgängen der Bursa in der Nähe ihrer Eingangsspalte an, während die blindgeschlossenen Endzipfel der Bursæ keine Genitalorgane tragen."

Ludwig regards these organs as internal gills, comparable to the external gills of the Starfish, the contents of the body-cavity being brought into direct relation with the external water in each case. He further points out that the position of the genital organs in the immediate neighbourhood of the external slits shows that the more internal portions of the bursæ must have had other functions than merely to serve for the discharge of the genital products, while their presence in sexually immature individuals and in males goes to show that they are not exclusively marsupial organs.

The position of these genital slits at the sides of the ambulacra in Ophiurids is so remarkably like that of the so-called spiracles in *Orophocrinus stelliformis* (Pl. XI. fig. 9), that Ludwig was led to compare the hydrospires of the Blastoids with the bursæ of the Ophiurids; and he pointed out that the inner wall of the latter, *i. e.* that next the body-cavity, is more or less plicated and frequently strengthened by calcareous deposits. We regard this suggestion of Ludwig's as an exceedingly happy one, and are entirely of the opinion that the hydrospires of the Blastoids served both for the purpose of respiration and for the discharge of the genital products. *Orophocrinus* has but one slit at each side of the ambulacrum (Pl. XI. figs. 8, 9; Pl. XIV. fig. 16; Pl. XV. figs. 2, 4, 5, 8, 10, 11, 13), like most Ophiurids; but in the genus *Ophiura* there are two slits opening into the same bursa, and occasionally separated from one another by some little distance, owing, as Ludwig puts it, to the approximation of the lateral walls of the primitively single cleft about the middle of its length. This is somewhat comparable to the difference between *Orophocrinus* and such a type as *Cryptoblastus melo* (Pl. VII. fig. 15), in which last the hydrospire-cleft is completely closed for some little way behind the spiracle owing to the lancet-plate coming into immediate and close contact with the deltoids. But along the sides of the radials the hydrospire-clefts open out again and each communicates with the exterior by a line of pores, owing to its being crossed by a series of small bridges between the hydrospire-plate and the side of the radial. Apart from this fact, however, there are two openings into each hydrospire-sac, an aboral and an adoral one, just as in *Ophiura*.

Unaware of Ludwig's happy comparison between the genital bursæ of an Ophiurid and the hydrospire-sacs of a Blastoid, Hambach has made some rather singular state-

[1] *Loc. cit.* pp. 273–282.

ments concerning the latter[1]. "It represents a membranaceous sack of peculiar construction, as it cannot very well be of calcareous lamellæ, admitting Billings' definition to be a correct one" (*i. e.* that the ambulacra are respiratory organs). Hambach gives no details concerning the peculiar construction of the hydrospire-sac; but we do not think that he would have had much doubt as to the calcareous nature of its walls if he had seen the specimens represented in Pl. X. figs. 13, 14, the first of which had already been figured by Rofe. Hambach goes on to describe the plication of the inner face of each hydrospire-sac and says that "these foldings are so arranged that they represent an unsymmetrical figure 8, of which the upper loop is larger than the lower one . . . . In such well-preserved specimens we may also observe that the upper loop of the plications surrounds, or that the cavity produced by these folds is filled out by, a tube, which I suppose to be the ovarian tube, and which has its outlet through the ten openings surrounding the *annulus centralis*; explaining, on the other hand, the necessity of the grooves for the support of the hydrospiric plication, which by this arrangement are kept from obstructing the free passage of the ovulum."

We have had some difficulty in understanding from the above description where Mr. Hambach believes the ovarian tubes to have been lodged; but from what he says in his subsequent paper[2] about the only space which could have been occupied by them being "below the hydrospiric sac and between the plicas," we conclude that he imagines every two of the lamellar tubes of each hydrospire-sac to have been separated by an ovarian tube which was outside the hydrospire-sac altogether and contained within the body-cavity. Thus, for example, there would have been six ovarian tubes on each side in *Pentremites pyriformis* (Pl. XVIII. fig. 3), three in *P. conoideus* (Pl. XVIII. fig. 6), two in *Mesoblastus elongatus* and *M. angulatus* (Pl. XVII. figs. 9, 10), and one in *Granatocrinus Norwoodi* and *Elæacrinus Verneuili* (Pl. XVII. figs. 8, 19). But what was the position of the ovarian tube in forms like *Granatocrinus campanulatus*, *G. Derbiensis*, *G. ellipticus*, *G. orbicularis*, and *Schizoblastus Rofei* (Pl. XVII. figs. 2–7), in which there is but one hydrospire-tube on each side of the ambulacrum? For the hydrospire-sac is devoid of any "plicas," and has simple straight walls without any "upper loop" which could have been occupied by an ovarian tube.

We likewise fail altogether to understand how the ovarian tubes of *Pentremites pyriformis* could have communicated with the exterior through the spiracles if they were situated *below* the hydrospire-sac, as Hambach describes. The spiracles do not lead into the body-cavity at all, but only into the hydrospire-sac (Pl. I. figs. 6, 7; Pl. X. fig. 14; Pl. XII. fig. 13), and cannot therefore have communicated with

[1] Trans. St. Louis Acad. Sci. 1880, vol. iv. no. 1, p. 152.
[2] *Ibid.* 1884, vol. iv. no. 3, p. 542.

ovarian tubes beneath it. Nevertheless, Hambach describes a "cone-shaped body" on the summit of well-preserved specimens of *Pentremites sulcatus*[1], which "consists of little tubes running parallel with each other, and roofing in the summit of the calyx in a conical shape (but not the central opening). They protrude through the same apertures in which the hydrospires terminate; there are about five of these tubes to each aperture, which seem to correspond with the plicas of the hydrospiric sac, and if they extend down into the interior of the calyx, as I suppose they do, then the only space which could have been occupied by them is below the hydrospiric sac and between the plicas, because they are isolated tubes and consequently not a continuation of the hydrospires. This would explain the necessity of the solid support of the plicas, which was undoubtedly to prevent an obstruction in the passage of these tubes, which I take to be the ovarian tubes."

Not having seen the original of Hambach's description, we can naturally say but little about it. Nevertheless we much doubt whether this cone-shaped body is anything more than an aggregation of the proximal pinnules[2] as represented in Pl. V. fig. 28; and in any case we are at a loss to understand how ovarian tubes which occupy the position described by Hambach could open to the exterior through the spiracles. We see no reason for calling these openings "ovo-spiracles" as Hambach does. The name is not only rendered more cumbersome by the addition of two syllables, but it also becomes absolutely incorrect. For there is no reason to think either that the Blastoids were hermaphrodite, or that they were all females; while there must still be a certain amount of doubt as to whether the genital glands of the Blastoids may not have been situated in the pinnules and have liberated their products directly, just as in the Crinoids.

Hambach has further committed himself to the remarkable doctrine that the outer side plates (supplemental pore-plates of Roemer) of a Pentremite are the remains of collapsed tentacles which were in communication with the hydrospire-sacs and protruded through the pores at the sides of the ambulacra. He is careful to explain[3] that by "tentacles" he does not mean the pinnules, to which organs this name has often been erroneously applied by other authors; but he uses it to denote the softer and membranous ones, "such as occupy the pores of the ambulacral field in Echinoderms." It is difficult to understand what can have induced Hambach to revive Say's theory[4] that "the branchial apparatus communicated with the surrounding fluid through the pores of the ambulacræ by means of filamentous processes." For in the sixty years since Say wrote it had been discovered that the tentacles of an Urchin

[1] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, p. 542.

[2] See Chapter IV. p. 70.

[3] Trans. St. Louis Acad. Sci. 1880, vol. iv. no. 1, p. 151.

[4] Journ. Acad. Nat. Sci. Philad. 1825, vol. iv. pt. 2, p. 296.

communicate with a water-vessel situated in the middle line of the ambulacrum; while on the other hand it had also been pointed out that the marginal pores of *Pentremites* lead down into hydrospire-sacs at the sides of the ambulacrum, and that pores are absent both in *Codaster* and in *Orophocrinus*; so that these types could have had no tentacles and must therefore have differed very considerably from the remaining Blastoids. There is also a difficulty in understanding how a "soft and membranaceous" tentacle could have become transformed when collapsed into a solid limestone plate, the form of which varied according to the species of *Pentremites.* This difficulty was pointed out by one of us [1]; but Hambach's only reply [2] was to reiterate his previous statement, and to assert that the tentacles "form in their collapsed state the supplementary poral plates of Roemer, which, to the great surprise of Mr. Carpenter, are actually found preserved in an open condition from the Carboniferous period to the present time." He likewise gave a "transverse section of a restored ambulacral field," in which each hydrospire-sac is represented as communicating with a marginal tentacle, with what appears to be a sucking disc at its end, just as in an Urchin. If, as asserted by Hambach, the outer side plates of a Blastoid are the remains of collapsed tentacles, why are no outer side plates ever found in any fossil Urchin which, when living, must have had tentacles in abundance? and, secondly, where are the pores through which the tentacles were protruded in *Phænoschisma nobile*, *P. Archiaci*, and *P. Verneuili*, all species which have well-developed outer side plates? (Pl. XI. fig. 4; Pl. XIV. figs. 6, 9).

Hambach's statements, although put forward as matters of absolute fact about which there can be no possible doubt, are in reality nothing but expressions of individual opinion, which it is difficult to take seriously on account of his ignorance of some of the most elementary facts of Echinoderm morphology.

B. Descriptive.

1. *The Hydrospires.*

Although it is probable that the presence of hydrospires beneath or between the ambulacra is one of the essential characters of a Blastoid, it must not be forgotten that there are two genera in which these organs have not as yet been detected, viz. *Pentephyllum* and *Stephanocrinus.* The first-named is only represented by an imperfect cast of the calyx (Pl. XVI. figs. 14–16), while the nature of the ambulacral structures of *Stephanocrinus* is still very obscure. There is no external indication of hydrospires in *Astrocrinus*, though traces of them appear upon the inner faces of the radial plates (Pl. XX. figs. 4, 18, 20), just as in *Cryptoschisma*, *Orophocrinus*, and *Tricœlocrinus* (Pl. XVI. figs. 3, 4, 6; Pl. XVIII. fig. 11), but the spiracles of this

[1] Ann. & Mag. Nat. Hist. 1881, vol. viii. p. 423.
[2] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, p. 539.

genus are altogether unknown. Those of *Heteroblastus* are quite small (Pl. VI. figs. 3, 4), and nothing is known of its hydrospires except the internal markings upon the radials and deltoids. The hydrospires of *Acentrotremites* are also unknown, but we may infer that they are normal from the fact that the spiracles and hydrospire-pores are tolerably similar to the corresponding parts of *Cryptoblastus* (Pl. VII. fig. 15; Pl. XIII. fig. 19). In all the other Blastoid genera, however, we have been able to obtain a personal knowledge of the hydrospires, sometimes in two or more species, and in most cases also in very different states of preservation. Their structure will probably be most clearly understood if we commence by studying them in *Codaster* and its allies.

In the flat-topped species of *Codaster* which occurs in Britain, four of the interradial areas on the summit of the calyx are marked by a series of slits with intervening ridges (Pl. XIII. figs. 1, 4, 8). They lie parallel to the ambulacra, and cross the radio-deltoid sutures nearly at right angles. The slits are actual breaches of continuity in the substance of the calyx-plates (Pl. XIII. figs. 6, 7); they pass through the thin lateral portions of the deltoids, and also through the horizontally depressed upper parts of the radials (Pl. XII. fig. 8; Pl. XIII. fig. 7). All that is left then of the ventral surfaces of these plates is represented by the ridges between the hydrospire-slits. Each of the latter leads downwards into what has been well described as a "lamellar tube." Two of Rofe's sections showing respectively the upper and lower portions of these tubes are seen in Pl. XIII. figs. 5, 7, the first of which represents a section along the north-western face of the rubbed-down calyx shown in fig. 7; while the relations of the tubes to the body-cavity are still more clearly seen in the weathered specimen shown in fig. 6. The whole of one radial has been removed, thus exposing the tubes which dip inwards towards one another beneath the ambulacrum, as is also seen in Pl. XVIII. fig. 1.

In the American species of the genus the calyx is much less flat-topped than in *Codaster trilobatus.* The radials are no longer so wall-sided, and show traces of a division into body and limbs. The oral crests thus become prominent and the ambulacra lie in sinuses between them as shown in *C. pyramidatus*, *C. Hindei*, and also in *C. alternatus*, var. *elongatus* (Pl. XII. figs. 1–6; Pl. X. figs. 19, 20). The radio-deltoid sutures descend the sides of these sinuses, which are pierced by hydrospire-slits just as in *C. trilobatus*, and though as in that species (Pl. XIII. fig. 14; Pl. XVIII. fig. 1) one or more of the slits may be concealed by the projection of the side plates at the edges of the ambulacra, the majority of the slits are freely exposed and open directly to the exterior.

The same is the case in some species of the genus *Phænoschisma*, which differs from *Codaster* in the presence of hydrospires in the anal interradius, so that there are ten groups of hydrospire-slits instead of only eight. The little *P. Benniei* has but a few large and widely separated slits (Pl. II. fig. 37). But in *P. nobile* and

P. Verneuili (Pl. XI. figs. 1–6; Pl. XIV. figs. 8, 9) there are deep radial sinuses the steep walls of which are crowded with closely set hydrospire-slits, but few of which are concealed by the narrow ambulacra (Pl. XI. fig. 4; Pl. XIV. fig. 9). On the other hand, in *P. caryophyllatum*, *P. Archiaci*, and *P. acutum* (Pl. XIV. figs. 1–7, 11, 12) the sinuses are less deep and more nearly filled by the ambulacra. These are broad and petaloid, and conceal a considerable number of the hydrospire-slits which are excavated partly in the deltoid plates, but mostly in the radial limbs (Pl. XIV. figs. 3, 6, 11). This is well shown in the transverse vertical sections of the calyx in *P. Archiaci* and *P. caryophyllatum* which are represented in Pl. XVII. figs. 15, 16. The enlargement of each lamellar tube at its inner end so as to form a kind of sac is very well seen in these sections. In these species, therefore, while some of the hydrospires—those nearest the top of the sinus—open directly to the exterior, others can only do so partially, and others—those nearest the ambulacrum—are completely concealed. As regards the second group it may be noted that while the partially exposed hydrospires of *P. caryophyllatum* have their distal ends open [1] (Pl. XIV. figs. 3, 4), as is also the case in *P. Archiaci* (fig. 6), it is the proximal ends which seem to remain uncovered in *P. acutum* (fig. 11). This is due to the differences in the form of the ambulacra, as will be apparent to any one who examines the figures on Pl. XIV.

The side plates of *P. Archiaci* rather rest upon the lancet-plate than against it (Pl. XIV. figs. 6, 7); but in *P. acutum* and *P. caryophyllatum* they lie against its sides with much the same relation to it as the side plates have to the lancet-plate of *Pentremites* (Pl. I. figs. 5, 6; Pl. XIV. figs. 2, 3, 11), and they thus bridge over the deepest part of the radial sinus so as to convert it into a tunnel. The proximal end of this tunnel opens externally by a small pore close to the peristome, which represents the spiracle of *Pentremites.* In the only example of *Phænoschisma acutum* which shows the ventral side this spiracle is artificially enlarged by the removal of some of the side plates, just as in the specimens of *Pentremites elongatus* shown in Pl. I. figs. 5, 6.

This condition is seen very much more plainly in the remarkable genus *Cryptoschisma.* The hydrospire-slits are excavated in the sides of the radial sinus and cross the lines of the radio-deltoid sutures just as in *Codaster* (Pl. V. fig. 24; Pl. XIII. fig. 8); but the ambulacra are so wide that they are completely concealed, owing to the great size of the side plates which rest against and not upon the lancet-plate (Pl. V. fig. 23; Pl. XIII. fig. 20). The side plates are quite small, however, at the proximal ends of the ambulacra and fail to meet the deltoids, so that they leave spiracular openings. These lead into the hydrospire-canal which runs beneath the side plates, and into which the lamellar tubes open by their slit-like upper ends. The condition of the spiracles varies according to the relative sizes of

[1] See *antea*, p. 77.

the side plates and deltoids. Thus, for example, there are ten in the original of Pl. XIII. fig. 20, one on either side of each oral ridge, as in *Pentremites Godoni* (Pl. I. fig. 11); while the specimens shown on Pl. V. figs. 23, 24 have but five openings, as in the ordinary *Pentremites.* A vertical section of the hydrospires of *Cryptoschisma Schulzi* is seen in Pl. XVIII. fig. 2; while figures 3 and 4 on Pl. XVI. show their distal termination against the inner faces of the radials.

The transition between the two chief types of hydrospires in the Blastoids is presented by the genus *Orophocrinus.* Those of the Belgian species, *O. Orbignyanus* and *O. Puzos*, are constructed on the type of *Codaster* and *Cryptoschisma*; while some of the hydrospires in the English species, *O. verus* and *O. pentangularis*, have nearly the same relation to the calyx-plates as those of *Pentremites* (Pl. I. figs. 6, 7; Pl. XII. fig. 13). The two Belgian species are somewhat aberrant members of the genus, and but for the form of the calyx and the appearance of the deltoid plates externally they might well be referred to *Phænoschisma.* In *O. Puzos* one at least of the hydrospire-slits is visible on the side of the radial sinus above the ambulacrum (Pl. XIV. figs. 14, 15), and the latter, though fairly wide, is not sufficiently so to come into direct contact with the sides of the sinus, so that a cleft appears between the side plates and the radials which the former do not bridge over; and it leads downwards beneath the edge of the ambulacrum to the bottom of the radial sinus. As the side plates never meet the deltoids this hydrospire-cleft is nowhere converted into a canal, so that no spiracles are visible at its proximal end. Its nature is more clearly shown in *O. Orbignyanus* (Pl. XIV. figs. 16–18). This species varies a good deal in the amount of exposure of the hydrospire-slits. Thus, for example, on one side of the radial sinus represented on Pl. XIV. fig. 18, two slits are left uncovered at the sides of the ambulacrum; while both proximal and distal ends of a third are also visible, very much as in *Phænoschisma Archiaci* (Pl. XIV. fig. 6). But only one slit is completely visible on the other side, while the slits of the sinus represented on Pl. XI. fig. 10 are almost entirely covered by the wide ambulacrum, which, however, does not touch the sides of the sinus; for it leaves an intervening hydrospire-cleft which passes downwards above the slits, as is better seen in Pl. XIV. fig. 16. In the remarkable species *Orophocrinus pentangularis*, which is common to Belgium and to Britain, the radial sinuses are much reduced in width as compared with those of *O. Orbignyanus* (Pl. XIV. fig. 16; Pl. XV. figs. 5, 8); and their sides are tolerably steep, though rather low, owing to the comparatively horizontal position of the ambulacra, which does not necessitate any deep incision of the rather widely spread radials. The hydrospire-slits are consequently not situated at a little distance apart on the sloping sides of the radial sinus as in *O. Orbignyanus* and in *Phænoschisma* (Pl. XI. figs. 1–6, 10; Pl. XIV.); but they are crowded together at the sides of the ambulacra at the bottom of the sinuses (Pl. XV. fig. 10), very much as in *Pentremites* (Pl. I. figs. 6, 7). The section shown in Pl. XVII. fig. 14, however, indicates that

the uppermost of the seven slits, at any rate, are excavated in the substance of the calyx-plates, as in *Phænoschisma* (Pl. XVII. figs. 15, 16). The two inner hydrospire-folds have thickened edges (Pl. XV. fig. 10), and upon these, bridging over the gap into the visceral cavity, there rests the under lancet-plate, itself with a prominent rim.

Owing to the small size of the deltoids nearly all the hydrospires are supported by the radial limbs, as is well seen in the same figure (Pl. XV. fig. 10). It also shows that the visible hydrospires do not extend quite to the distal end of the sinus, though the tubes perhaps pass into the substance of the radials as in *Pentremites*, *Tricœlocrinus*, and other genera (Pl. II. fig. 31; Pl. III. figs. 6, 8; Pl. XVIII. figs. 11, 13). Both in the English and in the Belgian varieties of *O. pentangularis*, but especially in the latter, the radial sinus is reduced to a relatively wide hydrospire-cleft extending along the whole length of the ambulacrum. This is nowhere in contact with the sides of the sinus (Pl. XV. figs. 5, 8, 10; Pl. XVI. fig. 8), so that the slits open directly to the exterior through the hydrospire-cleft, the proximal end of which is not separated off as a spiracle any more than in *O. Orbignyanus* (Pl. XIV. fig. 16).

In the other English species, *O. verus*, however, the under lancet-plate which bears the ambulacrum, is in contact with the sides of the radial sinus for rather more than the distal third of its length so that the hydrospire-cleft is considerably shortened (Pl. XV. figs. 3, 4); though at the same time it is continued as a canal beneath the under lancet-plate. But its proximal end is nowhere bridged over by the side plates of the ambulacrum, and remains as the so-called linear spiracle (Pl. XV. figs. 2–4). Some of the hydrospire-slits are excavated in the radials, as in *O. pentangularis*, though the lamellar tubes into which they lead are more widely separated than in that species (Pl. XV. figs. 4, 10; Pl. XVII. figs. 13, 14).

In the typical species of *Orophocrinus* (*O. stelliformis*, Pl. XV. fig. 13) the hydrospires are entirely concealed by the under lancet-plate just as in *Pentremites Godoni* (represented in Pl. XII. fig. 16), and they open externally by linear spiracles at the sides of the ambulacra (Pl. XI. figs. 8, 9; Pl. XV. fig. 11). The sides of the radial sinus slope downwards towards one another beneath the lancet-plate (Pl. XVII. fig. 12), and the hydrospire-slits all pierce the substance of the radials just as they do in the Belgian species (Pl. XIV. figs. 14–18). There are five thin lamellar tubes on each side of the ambulacrum where they descend into the body-cavity; and they may often be found more or less well preserved after removal of the contained matrix, just as in *Codaster* and *Cryptoschisma* (Pl. XIII. fig. 6; Pl. XVI. figs. 3, 4). They are well shown in Pl. XV. fig. 15 and Pl. XVI. fig. 6.

In *Granatocrinus*, *Mesoblastus*, *Cryptoblastus*, and *Acentrotremites* we meet with an altogether different arrangement of the hydrospires from those of the Codasteridæ; and it will best be understood after an examination of its simplest form as

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presented in *Granatocrinus ellipticus.* The calyx-plates are relatively thin and not produced upwards in the interradial areas, so that the radial sinus has no great depth, and there is no room on its sides for any hydrospire-slits. But a hydrospire-sac with strongly plated walls is attached to either edge of the radial sinus, and hangs down freely into the body-cavity. This is well shown in the weathered specimens of *Granatocrinus ellipticus*, which are represented on Pl. X. figs. 13, 14, and also in the sections shown in Pl. XVII. figs. 2–10. Each hydrospire-sac may consist simply of one lamellar tube dilated at its lower end as in *Granatocrinus ellipticus*, *G. campanulatus*, *G. Derbiensis*, *G. orbicularis*, and *Schizoblastus Rofei* (Pl. XVII. figs. 2–7); or there may be two tubes to each sac as in *G. Norwoodi* (fig. 8), three as in *Mesoblastus angulatus* and *M. elongatus* (figs. 9, 10), or five as in *Schizoblastus Sayi* (fig. 1).

The duplex character of the hydrospire-sacs of *Granatocrinus Norwoodi* and their relation to the radials is well shown in the internal views of them which are given on Pl. VII. figs. 1, 2. The outer plate of each lamellar tube is attached to the edge of the radial and does not appear externally except when the radial is removed, as shown in Pl. X. figs. 12, 14. But the inner plate comes up to the surface from beneath the lancet-plate which rests upon it, as seen in fig. 14. Between this inner plate, which we have called the hydrospire-plate, as explained above [1], and the edge of the radial sinus is the cleft-like upper opening of the hydrospire-sac, broken up into a series of pores by the repeated connections of the hydrospire-plate and the radial (Pl. IV. fig. 4; Pl. VI. fig. 10; Pl. VII. fig. 15; Pl. VIII. fig. 20; Pl. IX. figs. 7, 16; Pl. X. figs. 8, 11, 12; Pl. XI. figs. 11–15).

The adhesion between the hydrospire-plate and the radials is well seen in the weathered fragments of *Granatocrinus Derbiensis* which are represented on Pl. XI. figs. 11–13. The two last figures show the distal ends of the ambulacra, one (fig. 12) with and the other without the worn lancet-plate *in situ*. In the latter case, and also in the *G. ellipticus* shown in Pl. X. figs. 12–14, the gap between the two hydrospire-plates leads down into the general cavity of the calyx, as is evident from the sections represented on Pl. XVII. figs. 4, 6, 7. Fig. 11 on Pl. XI. shows a similar condition of weathering near the middle of an ambulacrum of *G. Derbiensis*. The impressions of the side plates are visible on the lancet-plate, as is seen on one side of the better preserved individual figured on Pl. IX. fig. 7, the plates being *in situ* on the other side. In *G. campanulatus*, *G. ellipticus*, and *G. orbicularis* there is much the same condition as in *G. Derbiensis* (Pl. VIII. figs. 15, 20; Pl. IX. fig. 16). The lancet-plate is wide and the hydrospire-plate scarcely exposed except where the lancet-plate is removed, or near the tip of an ambulacrum, and the same is the case in *Cryptoblastus melo* (Pl. VII. fig. 15).

[1] *Antea*, p. 49. See also Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 215.

But in *Acentrotremites* (Pl. XIII. fig. 19) and *Mesoblastus* (Pl: IV. fig. 4; Pl. VI. fig. 10; Pl. VIII. fig. 6; Pl. XI. fig. 15) the lancet-plate is relatively narrow, and does not fill the radial sinus, so that the side plates rest partly upon it and partly upon the sloping hydrospire-plate, which is moulded to receive them; and this condition also presents itself in *Granatocrinus Norwoodi* (Pl. XI. fig. 14). We have not been able to get any satisfactory sections showing this point, the best being that of *Mesoblastus angulatus* (Pl. XVII. fig. 9).

The formation of the pores between the hydrospire-plate and the radials is well seen in the moulds of the interior of the calyx of *Granatocrinus Norwoodi*, which are figured on Pl. VII. figs. 7–9. The last of these figures represents a specimen from which the original limestone plates have not been entirely removed, and the relations of the lancet-plate and deltoids to the surface of the mould beneath them are very clearly shown. The hollow impression lodging the lancet-plate is bounded—outside the limit of the deltoids—by a strong ridge, which is broken up transversely into a number of smaller portions. This is the cast of the upper part of the hydrospire-sac, the cleft-like opening of which is divided up into a series of pores in the manner already described; but this subdivision is not always so evident in the casts as is seen in Pl. VI. figs. 19, 20. Many of these moulds of *Granatocrinus Norwoodi* are hollow, and in their interior may be seen the duplex sac-like portions of the hydrospires, just as is shown in Pl. VII. figs. 1, 2. In many of the internal casts of *Schizoblastus Sayi*, though not of *Granatocrinus Norwoodi*, the ridges representing the hydrospire-sacs go but a very short distance beyond the radio-deltoid sutures, although the external ambulacrum with its marginal pores reaches far down into the radials, the limbs of which are twice as long as the body. A similar inequality in the internal and external aspects of the ambulacra appears in many *Pentremites*, notably in *P. conoideus* (Pl. III. figs. 4–6); and its occurrence in *Schizoblastus Sayi* will be better understood when the structure of the Pentremite type has been considered.

Except in one essential particular the general relations of the hydrospire-sac are the same in *Pentremites*, *Pentremitidea*, and *Troostocrinus*, as in *Mesoblastus* and *Granatocrinus*. The point of difference is the absence of any hydrospire-plate in the three first-named genera, so that when the side plates of the ambulacra are removed the hydrospire-slits are directly exposed (Pl. I. figs. 6, 7; Pl. IV. figs. 12, 14; Pl. V. fig. 3; Pl. XII. figs. 12, 13). The same is the case in *Orophocrinus Orbignyanus* and in *Phænoschisma acutum*, *P. Archiaci*, and *P. caryophyllatum* (Pl. XI. fig. 8; Pl. XIV. figs. 2, 3, 6, 7, 11, 16); but the hydrospire-slits of these two generic types are mostly situated on the sloping sides of the radial sinus and not concentrated in its deepest part, as in the Pentremitidæ and *Troostocrinus*, and to some extent also in *Orophocrinus verus* and *O. pentangularis* (Pl. I. figs. 6, 7; Pl. XV. figs. 4, 10).

The complexity of the hydrospire-sac in *Pentremites* appears to vary very considerably. Thus in *P. elongatus* there are only three lamellar tubes on each side, as in

Mesoblastus and *Troostocrinus Reinwardti* (Pl. XVII. figs. 9, 10, 17; Pl. XVIII. fig. 4). *P. Godoni* and *P. conoideus* have four, like *Schizoblastus Sayi* and *Troostocrinus* (?) *lineatus* (Pl. XVI. fig. 19; Pl. XVII. figs. 1, 18; Pl. XVIII. fig. 6). The *P. sulcatus* of which we have made sections has four folds on one side and five or even six on the other (Pl. XVI. fig. 20; Pl. XVIII. fig. 5). The latter condition is due to a branch being given off from one of the lamellar tubes for a short distance, but not extending to any great length, as there is no sign of it in the section of the same calyx which is figured on Pl. XVI. fig. 20. Lastly, *Pentremites pyriformis*, like *Orophocrinus verus*, has seven hydrospire folds (Pl. XVII. fig. 13; Pl. XVIII. fig. 3).

In the broad ambulacra of *Pentremites* the side plates rest against the edges of the lancet-plate; and when the whole tripartite structure is removed the hydrospire-slits are directly exposed (Pl. I. figs. 6, 7; Pl. XII. figs. 13, 14). For the inner wall of each hydrospire-sac (*i. e.* that nearest the middle line) is not continued upwards above the slits, so that it appears on the surface of the ambulacrum as the hydrospire-plate as in *Mesoblastus* and *Granatocrinus* (Pl. IV. fig. 4; Pl. VI. fig. 10; Pl. VII. fig. 15; Pl. VIII. fig. 6; Pl. X. figs. 11, 12; Pl. XI. figs. 14, 15).

In a species with many hydrospire-folds, however, such as *Pentremites pyriformis*, only a few of the slits are exposed by the removal of the lancet-plate and side plates, for the remainder are hidden beneath the under lancet-plate (Pl. I. figs. 6, 7; Pl. XII. fig. 13); while in *P. Godoni* (Pl. XII. fig. 16) they are all as completely concealed by it as those of *Granatocrinus* or *Mesoblastus* by the hydrospire-plate (Pl. IV. fig. 4; Pl. X. fig. 11). Owing to the complete continuity of the under lancet-plate across the middle line of the ambulacrum we do not think that it can be compared to the hydrospire-plate of *Granatocrinus* as implied by Hambach [1]. For the latter dips down into the interior of the calyx without meeting its fellow, as shown in Pl. X. figs. 12–14, and our sections show that the same is the case with the corresponding part of the hydrospire-sac in *Pentremites* (Pl. XVI. figs. 19, 20; Pl. XVIII. figs. 3–5).

Just in the same way as the proximal end of the hydrospire-sac of the Pentremitidæ is more or less completely supported on the deltoid plates (Pl. I. figs. 6, 7; Pl. XII. fig. 13), so the distal end is received into the substance of the radial very much as already described in *Cryptoschisma* and *Orophocrinus*. In these types, however, the line of the hydrospire-folds is nearly at right angles to the body of the radial (Pl. XVI. figs. 3, 4, 6); while in *Pentremites* the axis of the radial coincides with that of the hydrospire-folds (Pl. III. figs. 6, 8, 9). The way in which this occurs is well seen in *Pentremites conoideus*. Fig. 8 on Pl. XVIII. represents the distal end of a radial of this type after removal of all the ambulacral structures, together with

[1] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, p. 538. See *antea*, chap. iii. pp. 45–50.

the hydrospire-sacs. These extended right down to the end of the radial sinus as it appears in an external view of the plate. But the inner face of the same plate (Pl. XVIII. fig. 7) seems to show a much larger body and correspondingly smaller sinus and limbs. This is due to the closure of the lower part of the sinus by an extension of the calcareous tissue forming the body and the lower ends of the limbs of the radial, which is seen deep down in the view of the plate from the outer side (Pl. XVIII. fig. 8). The consequence is that in a radial which retains both its ambulacrum and its hydrospires the former sometimes seems much longer on the outer face than the latter appear to be in an internal view [1] (Pl. III. figs. 5, 6). In reality however, the hydrospires extend to the full length of the ambulacrum, but their distal ends are contained (so to speak) within the substance of the radials, and so do not depend into the body-cavity at all. The impression of an ambulacrum on the upper surface of an internal cast is therefore much shorter than the ambulacrum itself, just as has been noted in *Schizoblastus Sayi*. This is excellently shown in Pl. III. fig. 4, which represents a partially exposed internal cast of *Pentremites conoideus*; while figs. 10–12 are different views of a cast of its variety *P. Koninckianus* with quite short ambulacral impressions, though in reality the ambulacra are much longer, as shown in Pl. II. figs. 16–23.

The enclosure of the ends of the hydrospire-sacs within the substance of the radials so as to shut them off from the body-cavity is not always so complete as in *P. conoideus*, but we believe it to be of very general occurrence in the genus. In Pl. II. fig. 13 is represented a section of a radial of *P. Godoni* just above the point at which it begins to enclose the hydrospires; while fig. 31 shows a similar section near the tip of an ambulacrum of *Pentremites sulcatus*. The number of folds in the hydrospire-sac is much reduced, only those nearest the middle line being continued to the extreme end of the ambulacrum, and a great thickness of radial intervening between them and the body-cavity. In the genus *Tricœlocrinus*, so far as we have been able to make out, the greater part of the length of the hydrospires is thus enclosed within the substance of the radials. Figs. 10, 11 on Pl. XVIII. are inner and outer views of the same radial; while fig. 13 represents a sectional view of the end of the plate seen in fig. 12, and another section is shown in fig. 14. The amount of surface which the hydrospire-sac would present to the water contained in the body-cavity must therefore have been extremely limited.

In *Troostocrinus Reinwardti* the hydrospires appear to reach the end of the radial sinus in the usual way. But in *T.* (?) *lineatus*, to judge from a fragment in Mr. Wachsmuth's collection, they lie within the substance of the radials for some distance from the end of the ambulacrum, as in *Tricœlocrinus*. This point may be of use if it should become necessary to limit the genus *Troostocrinus* to *T. Reinwardti*,

[1] Figs. 7, 8 on Pl. III. show that this is not always the case.

and find a new generic name for the remaining species hitherto referred to the genus, as hinted on p. 37.

The hydrospires of *Astrocrinus* seem also to have been more or less completely enclosed within the substance of the radials (Pl. XX. figs. 3, 4, 17–20); and the same was perhaps the case with *Stephanocrinus*. So far as we can judge from the scanty material at our disposal, the condition of the hydrospires beneath the regular ambulacra of *Eleutherocrinus* is very much as in *Mesoblastus* and *Granatocrinus* (Pl. XIX. figs. 3, 4). The two hydrospire-plates form a bed for the lancet-plate; and the side plates rest partly upon the latter and partly upon the sloping edges of the thin radials. The row of pores between the hydrospire-plate and the radials leads down into a constricted hydrospire-canal from which the individual hydrospire-tubes are given off laterally, so that they lie six-deep beneath each of the radial limbs (Pl. XIX. fig. 3). The nearest approach to this condition in other Blastoids occurs in *Schizoblastus Sayi* (Pl. XVII. fig. 1); but the tubes seem to disappear altogether towards the lower end of the calyx of *Eleutherocrinus*, a thickness of 4 millims. separating the sections represented on Pl. XIX. figs. 2, 3. This appears to be due, however, rather to the unusual shortness of the hydrospire-sacs than to their being enclosed within the substance of the radials, no trace of them appearing in the section figured in Pl. XIX. fig. 2.

2. *The Spiracles.*

The name "spiracles," as already explained, was suggested by Billings[1] for the ring of five or ten openings immediately surrounding the peristome of a Blastoid, and by which the more or less concealed hydrospire-apparatus communicates with the exterior in all ordinary Blastoids except some species of the Codasteridæ, in which types the slits open directly to the exterior (Pl. XI. figs. 1–6; Pl. XII. figs. 1–6; Pl. XIII. figs. 1, 4, 6, 8–12, 14). Their relations to the deltoids, lancet-plates, and side plates vary considerably in the different genera, and seem to us to afford valuable characters for systematic purposes.

In the only species of *Cryptoschisma* (Pl. V. figs. 23, 24; Pl. XIII. fig. 20), and in those species of *Phænoschisma* which have broad ambulacra, the spiracles, when present, are mere gaps which remain at the proximal ends of the radial sinus, owing to the side plates being so small that they do not come into contact with the deltoids. A small opening is thus left, which leads downwards into the sinus beneath the covering formed by the more distal and broader side plates. We have seen these openings, although they are very minute, in some specimens of *Phænoschisma caryophyllatum*, as is represented in Roemer's figure[2], and they would also appear to

[1] Amer. Journ. Sci. 1869, vol. xlviii. p. 82; Ann. & Mag. Nat. Hist. 1870, vol. v. p. 264.

[2] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. Taf. iv. fig. 16[c].

exist in *P. acutum*; though in the specimen shown on Pl. XIV. fig. 11 they are artificially enlarged by the removal of two or three side plates. They are possibly also present in *P. Archiaci* (Pl. XIV. fig. 6), but we have not been able to make them out distinctly. They are very evident, however, in *Cryptoschisma Schulzi*, and vary somewhat in their characters according to the relative sizes of the ambulacra and of the deltoid plates respectively. In the individual shown on Pl. XIII. fig. 20 each of the ten sets of hydrospires has its own opening at the proximal end of the radial sinus a little below the level of the median ridge on the deltoid plate. But in the specimen figured by Roemer [1], as in those represented on Pl. V. figs. 23 & 24, the ambulacra are not sunk so deep in the radial sinuses, and the two openings at the side of each deltoid ridge thus become confluent into one, which may be quite small as seen in Roemer's figure and in our fig. 24 on Pl. V., or extend outward for some little distance above the deltoid as in fig. 23. The latter condition appears to be a somewhat abnormal one, and to arise from the smallness or absence of the proximal side plates which do not meet one another above the deltoid ridge as is usually the case. There is thus the same difference between two individuals of *Cryptoschisma* as between the two examples of *Pentremites elongatus* shown on Pl. I. figs. 4 & 5, or between the *P. sulcatus* and *P. Godoni* represented on figs. 10 & 11 of the same plate. The spiracles of *P. Burlingtonensis* are but little more distinctly double than those of either of our specimens represented on Pl. I. figs. 5 & 11. But the species is placed by Hambach [2] in a different division of the genus *Pentremites* from *P. sulcatus* entirely on this account. The facts mentioned above, however, will serve to show how little reliance can be placed on Hambach's system of classification. His explanation of it will be best considered when we come to study the spiracles of *Pentremites*.

In the British species of *Orophocrinus*, as explained above, the hydrospires come to be concentrated towards the bottom of the radial sinus, and are more or less completely covered up by the under lancet-plate. This is sometimes narrow and linear, as in *O. pentangularis* (Pl. XV. fig. 10), and scarcely conceals any of the hydrospires, while the ambulacra lying above it are also narrow and do not come in contact with the radials, so that the remainder of the radial sinus appears as "the spiracles," long clefts on either side of the ambulacrum (Pl. XV. figs. 5, 8). But in *O. verus* the under lancet-plate is relatively larger and wider, and comes in contact with the sides of the sinus some little way from its distal end, so that the length of the spiracular cleft is considerably reduced, but to a somewhat variable extent, as appears from figs. 1–3 on Pl. XV. It is widest at the proximal end (Pl. XII. fig. 9), and gradually passes backwards into a mere slit until it finally disappears altogether.

The rare American species *O. gracilis* seems to be in much the same condition as

[1] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. Taf. iv. fig. 18 *b*.
[2] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, p. 544.

O. verus (Pl. XVIII. fig. 9). At each side of the elevated but linear ambulacrum is a narrow elongated slit, which becomes still finer when it passes beyond the limits of the deltoid, and is traceable for some distance along the sides of the ambulacrum. This is well shown in Meek and Worthen's figure [1], which we had copied (Pl. XVIII. fig. 9) before receiving a specimen of the type from Mr. Wachsmuth.

The other American species (*O. stelliformis*) appears, at first sight, to present a somewhat anomalous form of spiracle. In all the figures of it which have hitherto been published, the ambulacra are represented as quite narrow, and as separated from the spiracles by what appear to be actual portions of the radial and deltoid plates; so that these clefts would not be simply the lateral portions of the radial sinus which are left unfilled by the ambulacra, but would be actually excavated in the substance of the calyx-plates themselves; and in fact in our only section of this species (Pl. XVII. fig. 12) it does almost seem as if this were actually the case.

The spiracles are thus described by Meek and Worthen [2]:—"So-called ovarian openings, commencing one on each side near the inner ends of the pseudo-ambulacral, or arm-areas, and extending outward along the margin of a broad sulcus, and near the edges of these areas, for about half the length of the latter as very narrow slits, widest at the inner end, where they connect with the inner ends of the internal compressed tubes under the areas." And they also add the following foot-note:—"These slits seem, as it were, to cut off a thin slice from each of the edges of the anal and interradial pieces, as well as from the margins of the deep pseudo-ambulacral sinuses of the radials. These slices are thicker near the upper (inner) ends, where they sometimes become callous, and apparently anchylosed, in adult specimens, to the pore-pieces so as to give the pseudo-ambulacra the appearance of greater breadth there than is natural." In the same work [3] the spiracles of *O. gracilis* are described as follows:—"Openings usually called ovarian apertures, in the form of distinct elongated slits, widest at the upper end, and extending down apparently three fourths the length of the pseudo-ambulacra, so very close to the margins of the latter as scarcely to leave more than a very thin intervening space above and apparently none below."

From the passages just quoted and from the figures illustrating them, it would thus appear that Messrs. Meek and Worthen considered the apparent separation of the spiracles and ambulacra of *O. stelliformis* by portions of the radial and deltoid plates to be a character of specific value distinguishing it from *O. gracilis*. We were at first inclined to agree with this description of Meek and Worthen's, but we have since found that what appear to be portions of the calyx-plates between the spiracles and the proximal ends of narrow ambulacra in *O. stelliformis* (Pl. XV. fig. 11) are

[1] Report Geol. Survey Illinois, 1873, vol. v. pl. viii. fig. 6 *b*.

[2] *Ibid.* p. 466.

[3] *Ibid.* p. 468.

really the lateral portions of wide and somewhat petaloid ambulacra. In well-preserved specimens they are crossed by fine lines, continuous with, but less distinct than, those which start from the median groove. The latter separate the inner ends of the large triangular side plates, while the former separate their outer ends and are usually entirely obliterated (Pl. XI. figs. 8, 9; Pl. XV. fig. 11). It will be seen from the first of these figures that the lancet-plate is broad and nearly fills up the radial sinus. Its sides slope downwards rather steeply from the narrow median groove, and upon them rest the side plates, the section of which at the proximal ends of the ambulacra is nearly an equilateral triangle. The upper side is slightly incurved; and that portion of the curve which is immediately next to the food-groove is all that is usually represented as side plate in figures (Pl. XI. figs. 8, 9; Pl. XV. fig. 11). In reality, however, the whole surface between the food-groove and the cleft is formed by the side plates, but the divisions between them are much more marked near the food-groove than they are near the cleft. In fact, the broad outer portions of the plates seem to coalesce so completely that they look like parts of the calyx-plates intercalated between the sides of narrow ambulacra and the clefts, as implied in the quotation given above (Pl. XV. fig. 11). But in one specimen we have found that the side plates are readily separable (Pl. XI. fig. 8); and it is then apparent that their outer portions really belong to the ambulacra and are not parts of the calyx-plates. An approach to this condition occurs in the Belgian species *O. Orbignyanus*, in which there is a sort of thickened rim to the wide ambulacrum (Pl. XI. fig. 10; Pl. XIV. figs. 16–18).

This enlargement of the proximal side plates of *O. stelliformis* is much more marked in some specimens than in others (Pl. XI. figs. 8, 9; Pl. XV. fig. 11), and it is occasionally so very pronounced as to give quite a bent outline to that part of the hydrospire-cleft which remains open as the spiracle (Pl. XV. fig. 11); but it rarely extends to any great distance, and in some cases the clefts close up owing to the under lancet-plate meeting the radials but a very short distance beyond the radio-deltoid suture (Pl. XI. fig. 9; Pl. XV. fig. 13). In other cases the radial sinus seems to be somewhat deeper, and the lancet-plate relatively narrow. The hydrospire-cleft remains at the bottom of the sloping wall of the sinus, and the side plates rest in the angle between this wall and the lancet-plate. But they do not come in contact with the radial wall till some way down the ambulacrum, and the external opening of the radial sinus, which is the real spiracle, is thus somewhat longer than the internal one by which it communicates with the hydrospire-sac beneath it, as is well shown in fig. 8 on Pl. X.

It may be further noted that in *O. stelliformis* (Pl. XI. fig. 9; Pl. XV. fig. 11) the proximal ends of the spiracles are at a greater distance from the mouth than in *O. gracilis* (Pl. XVIII. fig. 9), or in either of the British species (Pl. XV. figs. 2, 5, 8). In this respect they resemble the openings in *Schizoblastus Sayi* (Pl. III. figs.

1–3) and in *Acentrotremites* (Pl. XIII. fig. 19). Another point of interest about the genus is that the two spiracles in the anal interradius always remain distinct from the anal opening, as in the two types just mentioned (Pl. XI. fig. 9; Pl. XIV. fig. 16; Pl. XV. figs. 3, 8, 11; Pl. XVI. fig. 10), and do not become confluent with it as in *Cryptoblastus* (Pl. VII. fig. 14), and in most species of *Pentremites*, *Pentremitidea*, and *Mesoblastus* (Pl. IV. figs. 1, 14, 17; Pl. V. figs. 2, 4, 7, 10, 13, 15, 16, 19; Pl. VI. figs. 7, 8, 13).

The structure of the spiracles in *Pentremites* may be easily derived from their condition in *Orophocrinus*, and especially in *O. verus*. If the dissected ambulacrum of this species be compared with the corresponding parts of *Pentremites pyriformis* (Pl. I. figs. 6, 7; Pl. XII. fig. 13; Pl. XV. fig. 4) a considerable amount of resemblance may be traced between the two types. In the latter, as in the former, the proximal ends of the adjacent deltoids approach one another beneath the intervening ambulacrum and form a bed for the lancet-plate; and a little further out they support the proximal ends of the hydrospire-folds. The slits intervening between these folds open into the bottom of the radial sinus, which is relatively narrow in *Orophocrinus verus* and incompletely filled by the ambulacrum; so that a portion of its proximal end is left uncovered at each side of the latter. This constitutes the spiracle, and it is separated from its fellow of the adjacent ray by the body of the deltoid plate which appears on the exterior of the calyx, as is well shown in Pl. XV. fig. 3 and Pl. XVI. fig. 10. In *Pentremites*, however, the radial sinus is wider than in the typical *Orophocrinus*, especially at its proximal end, where it encroaches considerably on the bodies of the deltoids at its sides, so that each of these becomes reduced to a mere septum-like ridge. This divides the flattened proximal end of the plate into two equal portions, which thus form the floor of the radial sinus and are only properly seen when the ambulacra are removed (Pl. I. fig. 6). The sides of these ridges, and in fact of the whole sinus, slope very gently downwards, and are marked by a transverse series of alternating ridges and furrows, which were first noticed by Troost [1] (Pl. I. figs. 5–7; Pl. XII. figs. 13, 16). They are not mentioned at all by Roemer [2], in whose figures the sloping sides of the radial sinus are represented as perfectly smooth; but they were described by Hambach [3], who gives a good figure of them. The furrows receive the narrow outer ends of the side plates, the broader inner ends of which simply rest against the edges of the lancet-plate without covering any part of it (Pl. I. figs. 5, 6; Pl. XII. figs. 13, 14; Pl. XVI. fig. 21). As the lancet-plate only occupies the middle of the radial sinus there is a wide space left on either side of it which leads outwards above the hydrospire-slits. This corresponds to the whole spiracle of *Orophocrinus* (Pl. XIV. figs. 16–18; Pl. XV. figs. 4, 8–10); but the

[1] Trans. Geol. Soc. Pennsylvania, 1835, vol. i. p. 227.

[2] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. I. Taf. iv. figs. 2, 3.

[3] Trans. St. Louis Acad. Sci. 1880, vol. iv. no. 1, p. 147, Pl. A. fig. 2.

greater part of it is bridged over by the side plates and converted into the hydrospire-canal (Pl. XVI. figs. 19, 20; Pl. XVIII. figs. 3, 5). The side plates, however, do not come quite down on to the flattened central ends of the deltoids; and the commencement of the radial sinus is thus left open as the spiracle, as is shown in Pl. I. figs. 5, 6, 11, and Pl. XVI. fig. 21. This is also seen in the two sections of the summit which are figured on Pl. XII. In the first one (*P. pyriformis*, fig. 15) the summit has been ground down so far that the proximal ends of the hydrospire-slits are exposed at the sides of the deltoid pieces, except in the anal interradius. The canal within the lancet-piece is seen in section in two of the rays, where a little further grinding would have shown its communication with the oral ring by the radial passage beneath the lancet-plate as in the other three rays. This is seen in the section of *Pentremites Godoni* (fig. 17), which has not been ground far enough for the hydrospire-folds to appear in the spiracle openings; while the two septa in the anal spiracle have nevertheless been almost entirely removed.

In some forms of *Pentremites* the central end of the deltoid ridge is not completely covered by the side plates of the adjacent ambulacra, and the spiracles then appear to be more or less distinctly double. Fig. 5 on Pl. I. represents a specimen of *Pentremites elongatus* in this condition; but in other examples of the same species, and in *P. sulcatus*, the side plates of the ambulacra are much larger, and meet one another above the deltoid ridge, so as to conceal it completely (Pl. I. figs. 4, 10). Only five openings are therefore visible round the peristome; and Say [1] made use of this character in the generic name *Pentremites*, which, as G. B. Sowerby [2], and subsequently also Roemer [3], pointed out, is more correctly written *Pentatrematites*. Cumberland [4], writing a few years later about the Kentucky Asterial Fossil, but in ignorance of Say's description of it, spoke of the "five open perforations which probably supported the arms being divided in the middle, as in many other encrinital bodies, and not at all, I think, likely to be ovaries." Troost [5], again, mentioned the presence of septa in the spiracles, while Müller [6] detected them in 1841, and further pointed out that the anal spiracle was not merely the largest, as mentioned by Gilbertson [7], but that it had two septa in it which divided the lateral spiracles from the median anal opening; and their true relations were subsequently explained by Roemer [8]. This point is well brought out in the casts of *Pentremites Koninckanus* which are shown on Pl. III. figs. 10–12. At each side of the impression of the lancet-plate is a thick rim

[1] American Journ. Sci. 1820, vol. ii. p. 36.

[2] Zool. Journ. 1828, vol. iv. no. 13, p. 89.

[3] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 324.

[4] Reliquiæ Conservatæ, 1826, p. 34.

[5] Trans. Geol. Soc. Pennsylvania, 1835, vol. i. p. 227.

[6] "Ueber den Bau des *Pentacrinus Caput Medusæ*." Phys. Abhandl. k. Akad. Wissensch. Berlin, 1841 [1843], p. 229.

[7] Zool. Journ. 1828, vol. iv. no. 13, p. 90.

[8] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. pp. 331, 332.

with denticulate edges. This is the cast of the hydrospire-canal with its roof of side plates and intervening pores. It is sometimes hollow, and its cavity communicates with those of the hydrospire-slits. The casts of the two hydrospire-canals at either side of each interradial approach one another at the summit, and their proximal ends represent the spiracles. In the anal interradius they are seen to be quite distinct in origin from the cast of the anal opening (Pl. III. fig. 12), though they are scarcely distinguishable from it at the summit (fig. 10). The same difference appears on comparison of the two figures 15 and 17 on Pl. XII. In the first case the summit has been ground away far enough to expose the hydrospire-folds in the spiracles, except in those at the sides of the anus, which are well separated from it. But in the other specimen, which has been less ground, the two septa in the anal spiracle are almost entirely removed.

Hambach[1] has recently attempted to describe the formation of the spiracles in the typical *Pentremites*, with which he associates two species that we refer to the Troostoblastidæ, viz.:—*P. Wortheni* and *P. Reinwardti*. But we cannot think he has been very successful, as some parts of his description apply to but a few species of the typical *Pentremites* only. He says for example, "The first division would comprise all those species in which the horizontal portion of the deltoid piece is very narrow, the sinus to both sides in the deltoids and lancet pieces comparatively large, and so surrounded by the zigzag plated integument that two of the so-formed openings appear externally only as one (see fig. 5*a*)." In this figure the spiracles are represented as formed by the apposition of notches in the lancet-plate and in the deltoids respectively, very much in fact as is shown in our figure of *Cryptoblastus melo* (Pl. VII. fig. 15); but there is no indication that the side plates take any part in the formation of the spiracles. In fact Hambach states in an earlier paper[2] that the lateral concave furrow of the lancet-plate "forms, in connection with the corresponding portion of the deltoid piece, the ovarian aperture." It would appear from his figure that the side plates take as little part in the formation of the spiracles of *Pentremites* as they do in *Cryptoblastus melo* (Pl. VII. fig. 15). We cannot pretend to make a general statement about all the species of *Pentremites* found in America, but so far as what Hambach calls the typical species are concerned, viz. *P. florealis* (i. e. *P. Godoni*), *P. sulcatus*, and *P. pyriformis*, his description and figures certainly seem to be somewhat incorrect; though we believe that they are more applicable to *Troostocrinus Reinwardti* and to Hall's *Pentremites Wortheni*. In all the typical Pentremites the side plates form a part of the distal boundary of the spiracle as shown in *P. sulcatus* (Pl. I. fig. 10) and also in Hambach's own species *P. hemisphericus* (Pl. XVI. fig. 21). The same thing appears in the dissected ambulacrum of *P. pyriformis* shown on Pl. I. fig. 6. The hollow in the surface of the deltoids on either side of the ambu-

[1] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, p. 544.

[2] *Ibid.* 1880, vol. iv. no. 1, p. 149.

lacral opening and the proximal ends of the hydrospire-folds just beyond it, are not completely covered by the lancet-plate, as it does not come into such close contact with the deltoids as is represented in Hambach's figure. The lancet-plate and the deltoid ridge (if long enough) merely form the lateral boundaries of a sinus which is closed distally and converted into an oval opening by the side plates that rest between the edge of the lancet-plate and that of the deltoid. Were there no side plates there would be no hole-like spiracle at all, but a continuous sinus for some little distance along each side of the lancet-plate, very much as in *Orophocrinus stelliformis* (Pl. XI. fig. 8). This is well shown in Pl. I. fig. 5.

Hambach's omission to notice the share which the side plates often take in forming the spiracle is the more surprising, as he mentioned in his earlier paper[1] how they close up the furrow on each side of the lancet-piece. This is less marked in *Pentremites Godoni* than in *P. sulcatus*, *P. pyriformis*, and *P. elongatus* (Pl. I. figs. 5, 6, 10, 11); but we have never seen any Pentremites in which the side plates of the ambulacra are altogether excluded from the distal border of the spiracle, as represented in Hambach's figure[2].

We do not deny that Pentremites exist, such as some varieties of *P. Godoni*, in which the outward continuations of the spiracular openings beneath the side plates do not lead over the tops of the hydrospire-slits, for these are covered by the under lancet-plate (Pl. XII. fig. 16). On the other hand the spiracles of *P. elongatus*, *P. hemisphericus*, and, as we believe, of most species of the genus, have their distal boundary largely formed by the side plates (Pl. I. fig. 5; Pl. XVI. fig. 21). The different ambulacra of the individual which is represented in Pl. I. fig. 5 vary among themselves in the extent to which the side plates share in forming the spiracles; but it is evident that when they are removed the spiracle is converted into a long sinus between the lancet-plate and the deltoid. This individual is remarkable in another way; for three of the spiracles are rendered double by the great development of the deltoid ridge or oral crest, which is often not visible at all in this species, owing to the side plates meeting above it as shown in fig. 4. The spiracles thus come to have the same character as those of *Pentremites Burlingtonensis*, which is placed by Hambach[3] in the same group as *Cryptoblastus melo* (Pl. VII. figs. 14, 15),

[1] Trans. St. Louis Acad. Sci. 1880, vol. iv. no. 1, p. 150.

[2] We beg to apologise to Mr. Hambach in advance if we have misinterpreted his diagrammatic figure of *Pentremites sulcatus*. It has given us a great deal of trouble. For he affords no explanation of the meanings which he intends to convey by the various depths of shading which he employs, except to say that the sinus "is so surrounded by the zigzag plated integument that two of the so-formed openings appear externally only as one"; and that "By *a* and *b* is the covering integument removed to show the sutures between (*a*) deltoid and (*b*) lancet pieces." These sutures, however, are equally plain in every part of the figure, and so we are quite at a loss to understand the meaning of the above remark. There are also ten large openings, not five, besides the anus, and the two of each interradial pair are represented as separated by a wide striated partition which passes our comprehension altogether.

[3] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, p. 545.

Schizoblastus Sayi (Pl. III. figs. 1–3), and *Mesoblastus crenulatus* (Pl. IV. fig. 1; Pl. VI. fig. 8), because there are ten distinctly visible openings.

In these three genera, however, the spiracles are formed in a different way from those of *Pentremites Burlingtonensis*, as will be explained subsequently.

The spiracles of the genus *Pentremitidea* are formed in a very similar manner to those of *Pentremites*, being sometimes divided by a septum and sometimes not. Thus for example there is no septum in our specimens of *P. Eifelensis*, *P. Gilbertsoni*, or *P.? leda* (Pl. V. figs. 2, 10, 13); while it is present in one or two of the spiracles of *P. clavata*, *P. angulata*, and *P. Roemeri* (Pl. IV. figs. 14, 17; Pl. V. fig. 15). In all the species of the genus the lancet-plate is more or less concealed by the side plates which rest upon it, but project beyond it so as to fill up the gap between it and the radial at its sides (Pl. IV. figs. 12, 14, 17; Pl. V. figs. 3, 4, 19).

They thus form the distal border of the spiracle exactly as in *Pentremites* (Pl. I. fig. 6; Pl. XVI. fig. 21), and when they are removed the spiracle is converted into a sinus at the side of the ambulacrum, as is seen in our figures of *Pentremitidea angulata* and *P. Malladai* (Pl. IV. fig. 14; Pl. V. fig. 19).

Both in *P. Paillettei* and in *P. Lusitanica* the ambulacrum is rather lower in the radial sinus than in other species of the genus, and the consequence is that the spiracles do not appear as large round openings, truncating, as it were, the interradial portions of the calyx (Pl. IV. fig. 17; Pl. V. figs. 2, 15) or separated from them by side plates (Pl. V. figs. 4, 10), as in some *Pentremites* (Pl. I. fig. 4). But the whole of the oral crest is visible from the point where the radial limbs terminate and the deltoids begin (Pl. IV. figs. 8, 10, 12); and the spiracles are minute openings at the sides of this crest which can only be seen at all in specially well-preserved examples such as that figured by Roemer [1]. A tendency to the same arrangement is seen in *Pentremitidea similis* and *P. Malladai* (Pl. V. figs. 16, 19).

Mesoblastus does not differ very much from *Pentremitidea* in the structure of its spiracles, though considerably so in the arrangement of the hydrospires. The latter type resembles *Pentremites* in the absence of any covering to those hydrospire-slits which lie at the sides of the (under) lancet-plate and are not concealed by it (Pl. IV. figs. 12, 14; Pl. V. fig. 3). But in *Mesoblastus* removal of the side plates does not expose the hydrospire-slits, which are all concealed by the hydrospire-plate as already explained (Pl. IV. fig. 4; Pl. VI. fig. 10; Pl. VIII. fig. 6). The deltoids are relatively larger than in *Pentremitidea*, appearing on the exterior of the calyx (Pl. VI. fig. 12; Pl. VIII. fig. 1). Their proximal ends have a tolerably wide ridge, at each side of which is the flattened portion that forms the floor of the spiracle (Pl. IV. fig. 1; Pl. VI. figs. 7, 8, 13; Pl. VIII. figs. 2, 6). This is bridged over by the side plates which reach from the lancet-plate to the body of the deltoid, and the tunnel thus formed leads in beneath the hydrospire-plate on which the side plates rest, as shown in Pl. VI. fig. 13. The presence of the median deltoid ridge or oral crest thus causes the spiracles to be double. But it is sometimes absent (Pl. VIII. fig. 4), just

[2] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. Taf. iv. fig. 17 *b*.

as in *Pentremites* and *Pentremitidea* (Pl. I. figs. 4, 5, 10; Pl. IV. fig. 17; Pl. V. fig. 15).

The spiracles of *Granatocrinus* differ from those of all other Blastoids in the fact that they actually perforate the centre of the deltoid piece, and are altogether independent of the lancet-plate and side plates of the ambulacra, neither of which takes any part in their formation (Pl. VII. figs. 3–6; Pl. VIII. figs. 12, 17; Pl. IX. figs. 5, 8, 14, 15). This causes a considerable modification in the relations of these openings to the hydrospire-sacs. In most other Blastoids the spiracle is merely a portion of the proximal end of the radial sinus, which is not completely filled by the lancet-plate and side plates (*Pentremites*, Pl. I. figs. 4–6; *Schizoblastus*, Pl. III. figs. 1–3; *Metablastus*, Pl. III. figs. 14, 15; *Cryptoschisma*, Pl. V. figs. 23, 24; *Mesoblastus*, Pl. VI. figs. 7, 8, 13; and *Orophocrinus*, Pl. XI. fig. 8).

The opening which is left in this way is bounded, partly by the proximal end of the deltoid and partly by the lancet-plate, either alone, as in *Cryptoblastus melo* (Pl. VII. fig. 15), or in combination with the side plates as in the Pentremitidæ (Pl. I. figs. 5, 6; Pl. V. fig. 19; Pl. VI. fig. 13; Pl. XVI. fig. 21). In all these cases the hydrospire-canal which leads backwards from the spiracle towards the hydrospire-sac passes over the concealed lateral portions of the deltoids, which meet one another beneath the central end of the lancet-piece (Pl. I. figs. 5–7; Pl. V. fig. 24; Pl. XII. fig. 13; Pl. XV. figs. 4, 10). But in *Granatocrinus* this is not the case at all. The lancet-plate together with the thin hydrospire-plate at its sides completely fills the sinus, just as in *Cryptoblastus melo* (Pl. VII. fig. 15). But there is no notch at the proximal end of the lancet or deltoid plate as in this species, by which the hydrospire-canal continued onwards beneath the contiguous edges of the exposed parts of the deltoids and the lancet-piece could eventually reach the exterior.

In *Granatocrinus Norwoodi* (Pl. VII. figs. 7–9) as in *Acentrotremites* and in *Cryptoblastus melo* (Pl. VII. fig. 15) the hydrospire-plate does not extend further upwards than the suture between radials and deltoids, which last plates are comparatively small in all three types. In *Acentrotremites* this is the position of the spiracles, while in *Cryptoblastus* they are nearer the peristome, as just described. But in *Granatocrinus* the hydrospire-canal has no such means of opening externally, as the lancet-plate comes into close contact with the deltoids (Pl. VIII. fig. 20), and it finds its way to the exterior by being continued onwards through the substance of the deltoids till it reaches the surface (Pl. VII. figs. 3–6, 10, 11). Its course is well shown in the internal casts represented in Pl. VI. fig. 20, and Pl. VII. figs. 7–9. As a general rule the two tubes piercing each deltoid, which communicate with the hydrospires of adjacent ambulacra, converge rather rapidly and meet one another some little distance before they reach the external opening; but in one specimen that we have seen they open separately (Pl. VII. figs. 12, 13), and one of the two openings is not so much a perforation in the substance of the deltoid as a notch in

its side, the border of which comes very near the ambulacrum. This indicates an approach to the condition of the spiracles in *Cryptoblastus melo* and *Schizoblastus Bailii* (Pl. VII. figs. 14, 15; Pl. XVI. fig. 12).

On the other hand, the single spiracle is sometimes distinctly divided into two parts by a septum, as in *Granatocrinus McCoyi* (Pl. X. fig. 8); and this condition suggests a comparison with *Pentremites elongatus*, *Mesoblastus Sowerbyi*, or *M. elongatus* (Pl. I. fig. 5; Pl. VI. fig. 13; Pl. VIII. figs. 2, 4). But the difference between the two types is really considerable; for the spiracle of *Granatocrinus* is entirely within the substance of the deltoid, while that of the Pentremitidæ is partly bounded by the side plates.

Granatocrinus resembles *Cryptoblastus* and the two Irish species of *Schizoblastus* (Pl. VII. figs. 14, 15; Pl. VIII. fig. 9; Pl. XVI. fig. 12) in the fact that the two posterior hydrospires have a common opening with the anus. The two hydrospire-canals do not meet the rectum till just before they reach the surface of the plate, as is shown in the internal casts (Pl. VII. figs. 3, 5, 7).

This perforation of the deltoid pieces of *Granatocrinus* by the proximal ends of the hydrospire-canals is a character which, so far as we know, occurs in no other Blastoid, with the partial exception of the allied genus *Heteroblastus*. According to Hambach[1] the "rostrum" of the deltoid piece in *Granatocrinus Norwoodi* "is horizontally so expanded that Nature found it necessary to perforate the same, in order to give an outlet to the ovulum;" while in his second paper [2] he tells us that the deltoid pieces of *Granatocrinus* are perforated "because the lancet-pieces do not reach far enough to the summit to enter into the composition of the spiracle-openings." He also gives a diagram of the summit in *G. Norwoodi*, in which the proximal ends of the lancet-pieces are represented as altogether outside the ring of spiracles, and relatively as far from the peristome as they are in *Orophocrinus stelliformis* (Pl. XI. fig. 9; Pl. XV. fig. 11). We quite admit that this is the case in some individuals, as seen both on the exterior of the calyx and on the casts (Pl. VII. figs. 7, 10); but even if it were universal, which it is not, we must confess that we cannot follow the relation of cause and effect in Hambach's statement. For we do not see why the relatively broad proximal ends of the deltoids should not be both perforated and separated by the lancet-plates. Thus, for example, the lancet-plates of the *Pentremites elongatus* represented on Pl. I. fig. 5, or those of *P. hemisphericus* (Pl. XVI. fig. 21) come very close up to the mouth; but we do not imagine that their position would be altered in the least if there were a perforation in the middle of each deltoid instead of the oral ridge. Neither do we understand how the perforation of the deltoids in *Granatocrinus Norwoodi* would be interfered with if they were a little further separated, so that the lancet-plates could approach the peristome rather more closely than

1 Trans. St. Louis Acad. Sci. 1880, vol. iv. no. 1, p. 153.

2 *Ibid.* 1884, vol. iv. no. 3, p. 545.

they do in the specimen which Hambach figured. In fact, the lancet-plates of the two posterior ambulacra do reach quite close enough to the summit to "enter into the composition of" the anal spiracle, but they do not do so (Pl. VII. figs. 3, 7, 10). Another objection to the teleological argument which he employs is, that there are some Blastoids, such as *Orophocrinus stelliformis* (Pl. XI. fig. 9; Pl. XV. fig. 11), in which the lancet-piece terminates some way from the summit, and the deltoids are not perforated; while there are many individuals, both of *Granatocrinus Norwoodi* and of other species of the genus, in which the lancet-plate comes quite close up to the peristome. There is a considerable variation in *G. Norwoodi* in the degree of approximation of the exposed parts of the deltoids, for in some individuals the lancet-plate comes up between them, and actually separates two of the spiracles. This is still better shown in our figures of *G. McCoyi* and of *G. campanulatus* (Pl. X. figs. 8, 10); for most of the side plates have fallen away, leaving their impressions upon the lancet-plate, which comes quite close up to the peristome betwen the spiracles.

This effectually disproves Hambach's assertion that the deltoids of *Granatocrinus* are perforated "because the lancet-pieces do not reach far enough to the summit to enter into the composition of the spiracle-openings," and shows the danger of generalizing upon insufficient data.

The spiracular openings upon the surface of the deltoids of *Granatocrinus* are often somewhat strongly marked, the proximal end of the plate having a different appearance from its more distal portion (Pl. VIII. fig. 17; Pl. IX. figs. 14, 15). In *G. McCoyi* there is a sort of thick rim all round the opening (Pl. VIII. fig. 12; Pl. X. fig. 8); this also appears in *G. campanulatus* (Pl. X. fig. 10), and is sometimes developed into a thick shield-like process immediately behind the spiracle (Pl. IX. fig. 8), an indication of which is also seen in *G. Derbiensis* (Pl. IX. fig. 5). In some forms of *G. Norwoodi* the spiracular opening is nearly flush with the general surface of the deltoid and not specially prominent (Pl. II. figs. 32, 33); but in others the margin of the opening is produced upwards into a little tube, as shown in Pl. II. figs. 34, 35, and Pl. VII. figs. 5, 6. It is worth notice that the interradials of *Cyathocrinus Gilesi* are described by Wachsmuth and Springer[1] as "each one provided along its upper face with a conspicuous central node." We do not imagine that these nodes were perforated like the spiracular tubercles in *G. Norwoodi*, as we believe that the respiratory and generative organs of *Cyathocrinus* were contained, not in the calyx, but in the arms; but there is a sufficient resemblance between the two structures to make it worth recording.

The curious genus *Heteroblastus* seems to be most nearly allied to *Granatocrinus* in the structure of its spiracles, for the two hydrospire-canals in each interradius lie in well-defined grooves on the inner surface of the deltoid; but they open separately at the base of the conical process at its proximal end, as shown in Pl. VI. figs. 3, 4.

[1] 'Revision of the Palæocrinoidea,' Part III. 1885, pp. 21, 33, pl. iv. fig. 2.

The spiracles are very inconspicuous, and have the same general relation to the ambulacra as those of *Schizoblastus*; but the manner in which the deltoids are grooved for the reception of the hydrospire-canals rather suggests that the type is more closely allied to *Granatocrinus*.

The mode of formation of the spiracles in *Acentrotremites*, *Cryptoblastus*, *Elæacrinus*, *Schizoblastus*, and *Metablastus* is not very different from that which presents itself in *Orophocrinus*. The two first genera resemble *Mesoblastus* and *Granatocrinus* in having an hydrospire-plate coming up between the lancet-plate and the wall of the radial sinus (Pl. VII. fig. 15; Pl. XIII. fig. 19); but this is altogether absent in the other types, as in *Pentremites*.

The position of the spiracles of *Acentrotremites* is very much the same as in *Orophocrinus stelliformis*, viz., commencing just in front of the radio-deltoid suture, and therefore some little way from the mouth (Pl. XI. figs. 8, 9; Pl. XIII. fig. 19); but the causes of this are not quite the same in the two genera. In the *Orophocrinus*, the proximal thirds of the deltoid plates approach one another very closely and the ambulacra lie upon their apposed edges (Pl. XI. fig. 9). Some little way from the mouth, however, the sides of the deltoid plates diverge rapidly until they almost meet the radio-deltoid sutures, so that the plates have an elongately hexagonal form. The radial sinus of *Orophocrinus stelliformis* does not therefore come so close up to the peristome as it does in most other Blastoids, *Granatocrinus* being, perhaps, the type which approaches it most nearly in this respect. The position of the lancet-plate in *G. Norwoodi* is well seen in the cast shown on Pl. VII. fig. 7, which may be usefully compared with the worn specimen of *Orophocrinus stelliformis* represented in Pl. XI. fig. 9. In this individual the pointed proximal end of the lancet-plate comes directly into contact with the deltoids, and this condition is continued outwards while the width of the lancet-plate increases; but when it begins to diminish again, the plate comes away from the deltoid, and a cleft, the spiracular opening, appears between the two, being continued across the radio-deltoid suture, and down the side of the ambulacrum until the lancet-plate, or rather, the under lancet-plate meets the radials and closes it up (Pl. XI. figs. 8, 9; Pl. XV. fig. 13).

In *Acentrotremites*, on the other hand, so far as can be judged from the ambulacrum figured on Pl. XIII. fig. 19, the lancet-plate comes close up to the peristome, just as in *Cryptoblastus melo* (Pl. VII. fig. 15), and is completely concealed by the side-plates of the ambulacrum. These gradually become broader and broader till they reach a point just inside the radio-deltoid suture, so that they fill up the rapidly increasing gap between the ambulacral edges of the deltoids. At this point, however, the edge of each deltoid is slightly notched, and as the side-plates do not extend into the notch, a gap is left between them and the deltoid, which is, in fact, the spiracle (Pl. XIII. fig. 19). Between this opening and the peristome there are no marginal pores to the ambulacrum; but on its distal side there seems in our only specimen to

be an hydrospire-plate, between which and the radials there are numerous pores, as in the closely allied genus *Cryptoblastus*, and also in *Mesoblastus* and *Granatocrinus* (Pl. IV. fig. 4; Pl. VI. fig. 10; Pl. VII. fig. 15; Pl. X. figs. 11, 12).

The anal opening of *Acentrotremites* is altogether distinct from the spiracles of its interradius, as it is much nearer the mouth, piercing the proximal end of a deltoid (Pl. XIII. fig. 19). In *Cryptoblastus*, however, the anus is confluent with the spiracles at its sides (Pl. VII. fig. 14). These are not constructed in quite the same way as those of *Acentrotremites*, as the pointed proximal end of the lancet-plate takes part in their formation (Pl. VII. figs. 14, 15). A wide median ridge rising from the crenulated apex of each deltoid separates two spiracular openings which are apparently constructed upon the same type as those of some *Pentremites*, more especially *P. Burlingtonensis*, viz., leading into an hydrospire-canal which is roofed in by side plates (Pl. VII. fig. 14); but the removal of the side plates does not expose the concealed parts of the deltoids which form the floor of the hydrospire-canal, as in *Pentremites* (Pl. I. figs. 5–7; Pl. XII. fig. 13), for at the central end of the ambulacrum the lancet-plate comes into direct and continuous contact with the deltoid without leaving any intervening pores, although the side plates rest upon it as usual (Pl. VII. fig. 15). The same is the case in *Acentrotremites* and in *Orophocrinus stelliformis* (Pl. XI. fig. 9; Pl. XIII. fig. 19; Pl. XV. fig. 11); but it is the natural result of the position of the spiracles at or near the distal ends of the deltoids, so that the hydrospire-canals do not extend beyond them towards the mouth, and no marginal pores are wanted at the proximal ends of the ambulacra.

In *Cryptoblastus*, however, the pointed proximal end of the lancet-plate is slightly notched, and there are corresponding notches in the deltoid plates at its sides, so as to form the spiracles which lead downwards beneath the lancet-plate into the hydrospire-canal. But this is altogether covered up by the lancet-plate along the whole length of the deltoids with which this plate is in close contact. Beyond the radio-deltoid suture, however, it comes away from the side of the sinus, and so makes room for the hydrospire-plate which forms the inner boundary of the hydrospire-canal; and the canal thus opens to the exterior through the series of pores which are formed between the hydrospire-plate and the radials, just as in *Mesoblastus* and *Granatocrinus* (Pl. IV. fig. 4; Pl. VI. fig. 10; Pl. VII. fig. 15; Pl. X. figs. 11, 12).

Cryptoblastus melo is taken by Hambach[1] as the type of his second division of the genus *Pentremites*, in which he also includes *Schizoblastus Sayi*, *Pentremites Burlingtonensis*, and *Mesoblastus crenulatus*. He says that it "would comprise all those species in which the deltoid pieces are very broad, the lancet-pieces very narrow, and the sinus for the formation of the spiracle-openings in both deltoid and lancet-pieces very little; the zigzag plicated integument corresponding to the narrow ambulacral field is not wide enough, so as to surround these openings fully, hence they have to

[1] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, p. 544.

remain separate, or, in other words, where we have ten distinctly visible openings." This passage is illustrated by a diagram of *Pentremites melo*, in which there are *eleven* openings shown just as in that of *Pentremites sulcatus*! As a matter of fact, however, there should only be *nine*, for the anus is confluent with the two posterior spiracles, as seen in our fig. 14 on Pl. VII. But this is not the only error in Hambach's diagram. The spiracles are placed too far from the peristome, and are consequently represented as further apart than they really are. His statement that the spiracles *have* to remain separate because the zigzag plicated integument is too narrow to surround them fully is another instance of his teleological arguments. But they are not worth discussing, because this supposed elastic integument is nothing else but the crenulation of the food-groove on the median line of the ambulacrum and of its lateral branches between the side plates, as pointed out on p. 59.

Cryptoblastus has an hydrospire-plate and a compound anal spiracle; *Acentrotremites* probably has an hydrospire-plate, but the anus is distinct from the posterior spiracles. Neither *Schizoblastus*, *Elœacrinus*, nor any of the Troostoblastidæ have any hydrospire-plate. But the Irish species of *Schizoblastus* (Pl. VIII. fig. 9; Pl. XVI. fig. 12), and also *Troostocrinus Reinwardti* and *T. Grosvenori*, have an anal spiracle, though in *Elœacrinus*, in the American species of *Schizoblastus*, and in the genera *Tricœlocrinus* and *Metablastus*, the anal opening is distinct (Pl. III. figs. 1–3, 14, 15; Pl. VI. fig. 16; Pl. XVIII. figs. 15, 16; Pl. XIX. figs. 15, 16). In all the four types last mentioned the spiracles are formed upon essentially the same plan. The ambulacra are narrow and often diminish in width as they approach the peristome, as is especially the case in *Elœacrinus* (Pl. XVIII. fig. 16); while the proximal end of the radial sinus encroaches on the sides of the deltoids so as to form a more or less conspicuous opening. One edge of this opening is bounded by the narrow ambulacrum, which soon comes into contact with the deltoid so as to close the distal border of the spiracle. But as the side plates only rest upon the lancet-plate without projecting beyond it, they take no part in the formation of the spiracle, and do not directly cover in the hydrospire-canal as is the case in the Pentremitidæ. They have nearly the same relation to the spiracle as in *Cryptoblastus* and *Acentrotremites* (Pl. VII. figs. 14, 15; Pl. XIII. fig. 19), except that the lancet-plate between them is not incised to form the edge of the spiracle as is the case in these two genera.

It may also be noted that the spiracles of such a form as *Metablastus lineatus* (Pl. III. figs. 14, 15) are very closely similar to those of some species of *Orophocrinus*, *e. g.* of *O. verus* (Pl. XV. figs. 2, 3). In each case the spiracle is the proximal end of the radial sinus, which is closed distally by the ambulacrum meeting its walls. But in the former type the hydrospire-canal, which is continued outwards beneath the ambulacrum, communicates with the exterior through the hydrospire-pores, which are really only constricted portions of the sinus not closed by

the ambulacrum; whereas in *Orophocrinus* no pores are left at all. For in the English and American species of the genus the distal portion of the ambulacrum is in immediate and continuous contact with the radials (Pl. XI. fig. 9; Pl. XV. figs. 1–5, 11).

The character of that portion of the deltoid plate which intervenes between the two spiracles in each interradius of the Nucleoblastidæ or Troostoblastidæ varies considerably. In *Acentrotremites* the spiracles are separated by the whole width of the deltoid (Pl. XIII. figs. 18, 19). In *Elæacrinus* and in *Schizoblastus Sayi* the proximal end of the plate between the spiracles is tolerably broad and flattened or even slightly concave (Pl. III. figs. 1–3; Pl. XVIII. fig. 16). In *Cryptoblastus melo* it is represented by a wide ridge (Pl. VII. figs. 14, 15), which is still more reduced in *Schizoblastus melonoides* (Pl. VI. fig. 16), and smaller yet in the two Irish species of this genus (Pl. VIII. fig. 9; Pl. XVI. fig. 12). The second of these (*S. Bailii*) presents a transition towards *Mesoblastus*, in which, however, the side plates project beyond the edge of the lancet-plate and rest on the hydrospire-plate, so as actually to cover in the canal beneath it, as shown in Pl. VI. fig. 13. There are also other links between the type of spiracles of the Nucleoblastidæ and Troostoblastidæ, and that of the Pentremitidæ. The deltoids of *Metablastus lineatus* were figured by Shumard [1] as visible in a side view of the calyx. But we believe this to have been an error, as in all the examples of this type which we have seen they do not appear in this position at all (Pl. III. figs. 14, 15). Their outer ends are overlapped by the radial limbs just as in the *Tricœlocrinus* figured on Pl. XIX. figs. 13, 15; and all that is visible of them in the summit is their proximal ends, each with a strongly marked oral ridge rising from its centre. This ridge separates the two slit-like spiracles just as the corresponding ridge does in *Schizoblastus Bailii* (Pl. XVI. fig. 12) or in some forms of *Pentremites Godoni* and *P. elongatus* (Pl. I. figs. 5, 11), though in the latter genus the side plates form the distal border of the spiracle, which is not the case in the Troostoblastidæ. In *Tricœlocrinus Woodmani* this ridge is only visible in the posterior interradius (Pl. XIX. figs. 15, 16), and the spiracles of the other four interradii have very much the same relation to the deltoid plates as those of some species of *Pentremitidea* (Pl. VI. figs. 16, 19); though the two genera differ altogether in the relation of the spiracles to the side plates of the ambulacra.

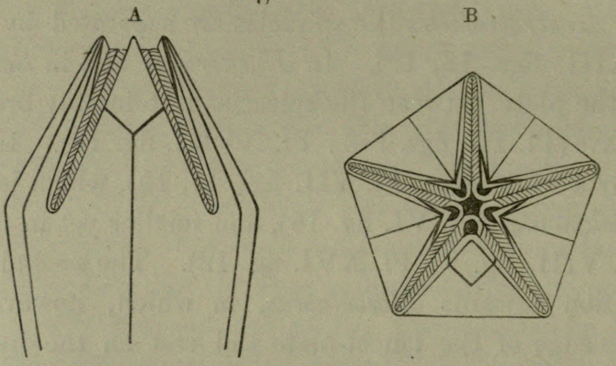
The spiracles of *Troostocrinus Reinwardti* are essentially like those of *Tricœlocrinus*, except that the posterior pair are confluent with the anus, while the anal deltoid is much larger than its fellows, and extends down on to the side of the calyx. Roemer [2] has given a good figure of the summit of this type, in which, however, the deltoids are erroneously represented as appearing externally in

[1] Trans. St. Louis Acad. Sci. 1858, vol. i. no. 2, pl. ix. fig. 3 *a*.

[2] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. Taf. iii. fig. 12 *b*.

each interradius. But it shows the relation of the spiracles extremely well. They are very minute slits at the sides of the knife-like central ends of the deltoids, and often almost as inconspicuous as in *Pentremitidea Paillettei* and *P. Lusitanica* (Pl. IV. figs. 8, 10, 12); but they are occasionally rather larger, as shown in our diagram (Fig. VII. B).

Fig. VII.



Diagrams of *Troostocrinus Reinwardti*. A. The anal side. B. Summit view. The radio-deltoid sutures are shown by rather darker lines.

It may be well for us to state here that acting upon information supplied to us by Mr. Wachsmuth since pages 36 & 37 were printed, and also by his desire, we have decided to restrict the generic name *Troostocrinus* to *T. Reinwardti*, which has the anal deltoid visible externally and a single anal spiracle (Fig. VII.); while we propose to take *Pentremites lineatus*, Shumard, as the type of a new genus *Metablastus* which has all its deltoids alike and the two posterior spiracles distinct from the anus (Pl. III. figs. 14, 15).

CHAPTER VI.

THE ZOOLOGICAL CHARACTERS OF THE BLASTOIDEA.

THE relative rank which should be assigned to the Blastoidea among the other groups of Echinoderms is still a subject of discussion; and it appears to us that Say, to whom we are indebted for the name of the group, had a much more correct notion of its systematic position than has been the case with many of his successors. He regarded the Blastoidea as a family intermediate between the two families of the Crinoidea and the Echinoidea [1]. The word family as employed by Say, Miller, and other writers during the first third of this century had a higher meaning than that which is given to it by the systematists of the present day. It rather corresponds to the orders or classes of modern zoology.

It is particularly noteworthy that Say did not place his new genus *Pentremites* in the "Family" Crinoidea which had been established by Miller but a few years before, though this might perhaps be inferred from the title of his paper. His reasons for establishing an altogether new "Family" of Echinoderms for the genus *Pentremites* are easily understood; although subsequent writers have ignored them altogether. In Miller's definition [2] of the family Crinoidea he described them as having "a cup-like body containing the viscera, from whose upper rim proceed five articulated arms, divided into tentaculated fingers more or less numerous." Well acquainted as he was with Parkinson's 'Organic Remains of a Former World,' he nowhere described the "Asterial Fossil" as one of the Crinoidea; nor did he include in this family any of the British species of *Granatocrinus*, *Mesoblastus*, or *Orophocrinus* from the Carboniferous Limestone of Lancashire, with one exception [3], though he cannot but have been acquainted with them.

In the same way the phrase "arms none" occurs in Say's definition of the family Blastoidea; while in his discussion of the affinities of the Pentremite-type he said, "By its columnar support it is related to the Family Crinoidea, but the total absence of arms and hands excludes it from that very natural group." On the other hand,

[1] Journ. Acad. Nat. Sci. Philad. 1825, vol. iv. pt. 2, pp. 292, 293.

[2] *Op. cit.* p. 7.

[3] He imagined *Orophocrinus pentangularis* to be the cup of a *Platycrinus*, and described the ambulacra as "the plates belonging to the integument that covers the abdominal cavity" (p. 84).

Caryocrinus, with arms springing from the rim of the cup, was considered by Say as a Crinoid, intermediate between *Cyathocrinus* and *Actinocrinus*.

There can be no doubt, therefore, that Say considered the Blastoids to be a group of Echinoderms of equivalent rank with Crinoids and Echinoids, and this is also the view which we take of their zoological position.

The group does not seem to have been definitely mentioned either by von Buch or by Edward Forbes, though they both regarded the Cystids and Crinoids as separate orders of Echinoderms, but ranked *Caryocrinus* with the latter, owing to its having arms attached to the rim of the cup. Forbes [1] stated, however, that "the absence of an ovarian pyramid is sufficient to show that the Pentremites are beyond the bounds of the Cystideæ;" and he believed their position to be between this group and some higher order of Echinodermata.

The Cystidea were regarded by Volborth as true Crinoids on account of the arm-like appendages which he found to occur in some of them. Roemer accepted this view, and classed not only the Cystids but also the Blastoids as families of the order Crinoidea, because of their pedunculate nature. He admitted, however [2], with respect to the Blastoids, that "obgleich ihnen freie Arme fehlen, so lassen sich doch die mit Pinnulæ-ähnlichen Anhängen besetzten Pseudambulacral-Felder als mit der Kelchschale verwachsene Arme betrachten, und diese entwickeln sich eben so vom dorsalen Pole des Körpers aus, wie die Arme der eigentlichen Crinoiden."

This step on Roemer's part has led to much confusion of terms, the word Crinoidea having been variously used to designate only the truly brachiate forms for which it was proposed by Miller, or as a comprehensive term for all the Stalked Echinoderms. Miller's definition of the Crinoidea was an explicit one, and Say's "arms none" still more so as regards the Blastoids; while three years before the publication of Roemer's monograph Leuckart [3] had proposed the "Pelmatozoa" as a class embracing three orders, Crinoids, Blastoids, and Cystids. This fact seems to have been unknown to Roemer [4], even as late as 1852, when the 'Lethæa Geognostica' was published. He then raised the Blastoids from family rank to that of a suborder, still keeping them, however, distinct from the Cystids; and he regarded both groups as equivalent in value to the truly brachiate Crinoids, which he proposed to call the "Actinoidea." Bronn [5], on the other hand, considered the Blastoids as a distinct class of the "Strahlenthiere," for which he proposed the name "Blastactinota;" and he reinstated the Cystids among the brachiate Crinoids, with the class name "Crinactinota." Burmeister [6], a few years previously, had taken an opposite course

[1] Mem. Geol. Survey Gt. Brit. 1848, vol. ii. pt. 2, p. 528.

[2] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. 1, p. 387.

[3] 'Ueber die Morphologie und die Verwandtschaftsverhältnisse der Wirbellosen Thiere' (Braunschweig, 1848), p. 42.

[4] 'Lethæa Geognostica,' 1852, Bd. i. Th. 2, p. 224.

[5] 'Die Klassen und Ordnungen des Thier-Reichs,' Bd. ii. 1860, p. 180.

[6] 'Zoonomische Briefe' (Leipzig, 1856), vol. i. p. 243.

and separated the truly brachiate Crinoids from the Blastoids and Cystids, which he proposed to group together as "Anthodiata," though, like Roemer, he extended Miller's name Crinoidea to include the armless Blastoids, in ignorance of the fact that the foresight of Leuckart had already provided a better one.

There is much to be said for this classification of Burmeister's, the principle of which has been adopted by Wachsmuth and Springer, as we shall see subsequently. The remarkably unsatisfactory arrangement of d'Orbigny and his countrymen, who grouped the Blastoids and Cystids as families of the Crinoidea equivalent to the Comatulidæ and Pentacrinidæ, needs no further notice, as it has been superseded by others which give better expression to important morphological differences. Claus[1] in 1876, and subsequently Zittel and de Loriol, adopted the principles of Roemer's classification, regarding the Blastoids, Cystids, and true Crinoids as orders of the class Crinoidea, this being itself equivalent to Echinoidea, Stellerida (Asterids and Ophiurids), and Holothurians.

In this country, however, the ideas of Miller and Say, of von Buch and Forbes, have more generally prevailed, and Crinoids, Cystids, and Blastoids have usually been regarded as independent but equivalent groups of the Echinodermata, of the same rank as the Urchins, Holothurians, and Starfishes; and in accordance with the elevation of the Echinoderms to the rank of a subkingdom, its ordinal divisions have become classes. In the fourth edition of Claus's 'Grundzüge,' which was published in 1880, this rank is assigned to each of the three groups of Stalked Echinoderms, as it is to the Urchins and Starfishes.

The same course was taken in the Report on the 'Challenger' Crinoids[2], but Leuckart's name Pelmatozoa was revived for the Stalked Echinoderms, which, in accordance with his suggestion and the later ones of Huxley and Ray Lankester, were regarded as forming a distinct primary division of the subkingdom. Ludwig[3], the leading German authority upon Echinoderms, has since adopted this classification, and divides the Echinoderms into two primary groups, the Actinozoa[4] and the Pelmatozoa, the first including four and the latter three classes. This differs slightly from Leuckart's arrangement, in which the Holothurians are separated as Scytodermata from the Actinozoa on the one hand and from the Pelmatozoa on the other. We are inclined to believe that the former is probably the best arrangement; but whichever of these two systems be eventually accepted, we feel that there can be little doubt as to the value of the Pelmatozoa as a "primary division of

[1] 'Grundzüge der Zoologie,' Dritte Auflage (Marburg und Leipzig), 1876, Bd. i. p. 279.

[2] Zool. Chall. Exp. Part xxxii. 1884, p. 186.

[3] Dr. Johannes Leunis 'Synopsis der Thierkunde,' Dritte Auflage, 1886, Bd. ii. p. 878.

[4] This name, which is due to Latreille, was employed by Leuckart for the Urchins and Stellerids together; but in this country it is generally used to designate the Corals and their allies, which are known in Germany by Ehrenberg's name Anthozoa. We prefer therefore to adopt the course taken by Sir Wyville Thomson in a Syllabus of his Class Lectures on Zoology which was published at Edinburgh in 1878, and to use "Echinozoa" as a comprehensive term including the Urchins, Stellerids, and Holothurians.

Echinoderms." This position was assigned to them independently by Professors Leuckart, Huxley, and Ray Lankester; and the course taken by these distinguished naturalists has received the approval of the late Sir Wyville Thomson and Dr. Carpenter, of Mr. Percy Sladen, and lastly of Professor Hubert Ludwig.

Messrs. Wachsmuth and Springer [1], however, while employing Leuckart's name Pelmatozoa, use it only as equivalent to Crinoidea as defined by Roemer, Zittel, and de Loriol, *i. e.* merely as a class name, of equal rank with Urchins, Starfishes, or Holothurians.

They admit that the Stalked Echinoderms are more distinct from either of the three groups of Echinozoa than these are among themselves; but they doubt the necessity of expressing this in a classification for fear of its becoming encumbered by too many subdivisions. There appear to us, however, to be just as good reasons for dividing the Echinoderms into branches Echinozoa and Pelmatozoa, as for making Branchiata and Tracheata primary divisions of the Arthropods, or for grouping the five classes of Vertebrates into Ichthyopsida, Sauropsida, and Mammalia. Leuckart [2] pointed out in 1848 that the result of the researches of Miller and Müller was to show "dass die Crinoiden keineswegs mit den Asteriden vereinigt werden dürfen, dass sie vielmehr eine besondere, u. a. durch fundamentale Unterschiede in der Skeletbildung ausgezeichnete Gruppe bilden."

To any one acquainted with the progress of Echinoderm morphology during the last forty years this sentence will have an even deeper meaning than it had when Leuckart's most valuable essay was published in 1848. The remarkable neuro-vascular system which is situated in the anti-ambulacral region of a Crinoid and extends downwards into the stem, probably to control its movements and those of the cirri which it often bears, was utterly and entirely misunderstood by the majority of naturalists until quite lately; and we think that the American palæontologists can be scarcely aware of its morphological importance.

The only differences between the Pelmatozoa and the other Echinoderms to which they refer are purely of a physiological nature, viz. the absence of locomotor organs in connection with the ambulacral system, and the fact that a Crinoid lies on its aboral surface instead of creeping about with its mouth downwards in search of food. They conclude by saying [3], "All this, however, we think is sufficiently expressed by giving the Pelmatozoa the rank of a class, and placing them at the end of the list." But since "this" is not "all" we cannot accept their view of the systematic position of the Pelmatozoa, and, like Leuckart, Huxley, Haeckel, Ray Lankester, and Ludwig, we prefer to rank the group as a distinct "Branch" of the "Phylum" Echinodermata.

The authorities just mentioned, and also Roemer, Forbes, and Claus, have regarded the Brachiate Crinoids, the Cystids, and the Blastoids as groups equivalent to one

[1] 'Revision of the Palæocrinoidea,' Part III. 1885, p. 75. [2] *Op. cit.* p. 39.
[3] 'Revision of the Palæocrinoidea,' Part III. 1885, p. 75.

another and to the Urchins or Starfishes. This is also the classification which was adopted in the 'Challenger' Report, and will be employed in this Catalogue. During the earlier portion of our joint work on the Blastoidea it appeared to us that the group had several affinities with the Cystids, and it was stated by one of us [1] that they are "so closely linked together that it is extremely difficult to refer forms like *Hybocystites* and *Cystoblastus* to one group rather than to the other."

Of late, however, we have been led to the conclusion that the group Blastoidea is in reality an extremely well defined one, and that there is perhaps a closer affinity between Cystids and Crinoids through *Porocrinus* than between the former group and the Blastoids, no really intermediate type being known to us.

The following definition embraces the result of our seven years' study of the group. It is preceded by a definition of the Pelmatozoa which is based on that published in the 'Challenger' Report [2], and subsequently modified by Wachsmuth and Springer [3].

Phylum ECHINODERMATA.

Branch Pelmatozoa.

Echinoderms which are fixed either permanently or temporarily by the middle of the aboral surface. A jointed stem containing a neuro-vascular axis is usually present, but may be lost when maturity is reached ; or, in the case of a few sessile forms, remain altogether undeveloped. The apical system consists of a dorsocentral plate, basals, and radials, with the frequent addition of under-basals and interradials. These plates form a cup, which either simply supports, or more or less completely encloses, the visceral mass, and often bears jointed appendages—the arms and pinnules.

An oral system, which is to some extent a repetition of the apical system, and consists of a central plate, basals, radials, and interradials, is developed to a very variable extent above the actinal surface of the larva. It may be (1) altogether resorbed ; (2) persist as basals only which cover the peristome ; or (3) reach a high state of development so as to form a complex vault or *tegmen calycis* covering in the whole visceral mass. The anal tube opens on the oral surface, but is sometimes in close relation with the calyx-plates.

The water-vascular ring does not communicate directly with the exterior, and the lateral branches of the radial vessels (when present) are respiratory, but not locomotor in function.

Class Blastoidea.

Armless Pelmatozoa of a pyriform, clavate, ovate, or globose shape, which usually exhibits a very perfect radial symmetry. Base monocyclic, of two large plates and

[1] Zool. Chall. Exp. Part xxxii. 1884, p. 191. [2] *Ibid.* p. 186.

[3] 'Revision of the Palæocrinoidea,' Part III. 1885, p. 79.

one small one, the latter being always in the left anterior interradius (A–B). Five radials, more or less deeply incised by the ambulacra, and five interradials which rest on them and bound the peristome, one of them being pierced by the anus.

Ambulacra fringed on each side by a single or double row of jointed appendages, which are in close relation with the side plates. These rest on or against a subambulacral lancet-plate, which is pierced by a canal that lodged the water-vessel and unites with its fellows into a circumoral ring.

Hydrospires arranged in ten (or rarely eight) groups which are limited to the radial and interradial plates; their slits are parallel to, and more or less completely concealed by, the ambulacra, often opening externally through pores at their sides, and also by five or ten openings round the peristome. Neither hydrospires nor ambulacra extend below the basiradial suture.

Peristome naturally concealed by a vault of small plates, which rarely exhibit any definite arrangement, and are continuous with the covering plates of the ambulacra.

Remarks.—Of the various characters mentioned in the preceding definition some are important because they occur in no other Pelmatozoa, while others, though absolutely constant among the Blastoids, seem to present themselves exceptionally in both Crinoids and Cystids. Others again depend not so much on the presence of particular structures, as on their mode of distribution in the organization of a Blastoid. To the first class belong the perforation of the lancet-plate, of which we have as yet no knowledge whatever in either Crinoids or Cystids. In the second class come the absence of under-basals, the constant presence of five interradials (one of which is divided in *Elæacrinus*), and likewise perhaps the constant but peculiar trimerous symmetry of the base, which seems to occur also in the rare Cystid *Cryptocrinus cerasus*, but in no Crinoid at all with the possible exception of *Stephanocrinus*. Many Palæocrinoids have a trimerous base, but according to Wachsmuth and Springer [1] the small plate is always in the right anterior interradius (A–E).

Chief among the third class of characters of the Blastoidea is the very symmetrical grouping of the hydrospires. These organs occur in most Cystids and perhaps even

[1] 'Revision of the Palæocrinoidea,' Part III. 1885, p. 10. The words *left* and *right* are used by the American authors in a different sense from that in which we have employed them, as explained above on pp. 13, 14; and we cannot help thinking that in their description of the azygos basal of Palæocrinoidea as being located between the anterior and left posterolateral ray, the word *anterolateral* would have been more correct than *posterolateral*. Since the preceding pages were printed Mr. Wachsmuth has kindly sent us an advance sheet of the forthcoming concluding portion of the 'Revision of the Palæocrinoidea' by himself and Mr. Springer. In this work, evidence is adduced, which in our opinion is conclusive, to show that *Stephanocrinus* is no Blastoid at all, but a Brachiate Crinoid. In the few specimens in which we have been able to make out the position of the small basal of *S. angulatus* (including two which were sent to us by Mr. Wachsmuth himself) it occupies the same position as in the Blastoids, viz. the interradius A–B, as shown in our diagram on p. 17. The American authors state, however, that the small basal of *Stephanocrinus* is directed towards the azygos side, which is the interradius C–D of our nomenclature; and as they have examined a large series of specimens both of *S. angulatus* and of *S. gemmiformis*, this is probably true.

in some Crinoids, but we know of no member of either group in which their arrangement is at all like that which occurs in the Blastoids. In this class they are restricted to the radial and interradial plates, where they lie with their slits parallel to the ambulacra, and, except in the genus *Codaster*, there are always five interradial pairs of hydrospire-groups. No Cystid whatever presents anything like this regular distribution of the hydrospires, which often extend down on to the basals, and even on to the under-basals, when such are present.

Considered as a whole, the Blastoids have the most regularly constructed calyx of any Pelmatozoa, and in fact of any Echinoderms. Under-basals may occur in all the brachiate forms, while the basals of Crinoids may vary in number from two to five, and the development of the interradials varies extremely among the different groups. The primitively simple apical system of an Urchin eventually undergoes very considerable modifications, while that of Stellerids is complicated by the great development of a number of additional plates. In the Blastoids, however, there is only one exception to the number of thirteen plates in the calyx, viz. *Elæacrinus*, which has the posterior deltoid divided into two by the anal plate; while, except in the three genera *Eleutherocrinus*, *Astrocrinus*, and *Pentephyllum*, the contour of the calyx is always perfectly symmetrical, consisting as it does of five equal and similar radials, and five deltoids of the same nature [1].

Taking then all these characters together, we find that the Blastoids constitute a remarkably compact group, which is pretty clearly marked off from the other Pelmatozoa; and we cannot at all agree with Wachsmuth and Springer [2], who say that the Crinoidea, "but especially the Blastoidea, are linked together with the Cystidea by such easy transitions, that among the earlier types it is difficult to draw any clear line of demarcation. We are unable to point out a single character that is not found exceptionally in one of the other groups." They give this as a reason for refusing the rank of a class to either Crinoids, Cystids, or Blastoids.

The relation between Crinoids and Cystids will be discussed by one of us elsewhere; but there is no difficulty in mentioning characters of the Blastoidea which are not as yet known to occur in either of the other groups. Such for example are the perforate lancet-plate, the regular limitation of the hydrospires to the radial and interradial plates, with their slits parallel to the ambulacra, both points of very considerable importance, as well in a morphological as in a physiological aspect. What Cystid has such a regular calyx as a Blastoid? *Cryptocrinus cerasus* seems to have the same symmetry in its base, but the rest of its calyx is constructed on a totally different plan from that of a Blastoid. The Lower Silurian *Cystoblastus* [3] has two rings of

[1] The anal deltoid is different from the rest in *Troostocrinus* (see pp. 36, 112), and slightly so in *Granatocrinus neglectus*, M. & W.

[2] 'Revision of the Palæocrinoidea,' Part III. 1885, p. 75.

[3] See Volborth, "Ueber *Achradocystites* und *Cystoblastus*, zwei neue Crinoideen-Gattungen." Mém. Acad. Imp. Sci. St. Pétersbourg, 1870, vii.e sér. tom. xvi. Mém. 2, p. 11.

four plates each below the radials, and some of them pierced by the hydrospire-slits. Other slits occur at the sides of the radials, but transversely to the ambulacra, while there are only four deltoids, which are in the same line with the radials and not above them. We cannot see any very striking Blastoid affinities here. The same may be said of *Asteroblastus*. This type has four basals and five deltoids, the two series being separated from one another by a group of small plates. The ambulacra and pinnules are at least as much like those of *Pseudocrinites* and other Cystids as those of any Blastoid. *Asteroblastus* has no lancet-plate nor interradial hydrospires; and we do not think that the "ambulacral pores" mentioned by Wachsmuth and Springer [1] are what that name implies, since we take them to be the sockets for the attachment of the pinnules, as was described by Schmidt [2], who further said "auf den Radien selbst keinerlei Poren." Lastly, as the small calycular plates above mentioned bear the well-known "double pores," we fail to see what characters, besides the very generalized one of five pinnule-bearing ambulacra, do link *Asteroblastus* with the Blastoidea. *Hybocystites* is another type which in some respects is very like a Blastoid, but the resemblance is more a superficial than a fundamental one, and we are inclined to regard it as less like a Blastoid than was thought by one of us in 1882 [3]. The pentamerous base on which two or more of the ambulacra terminate, the segmented extensions of three rays, and the azygos plates, all seem to us to suggest that the resemblance to a Blastoid is in a great degree superficial, and due rather to the appearance of the ambulacra than to any definite morphological characters.

There are various Lower Silurian forms from the Trenton group which are allied to *Hybocystites* and *Hemicystites*, and have been thought to represent a primitive Blastoid type. By the kindness of Professor Wetherby we have been permitted to examine some of these; but we cannot make out that they have any claim to admission into the very well-defined group Blastoidea. At the same time they are very different from the ordinary Cystids. This name is applied to a number of very different types; and we quite agree with Wachsmuth and Springer that a further subdivision of von Buch's original group is now necessary.

The only described form which appears to us to offer any real link between the Blastoids and the Crinoids or Cystids is the problematical *Blastoidocrinus*. So far as we are able to understand its characters from the descriptions of Billings [4] and Schmidt [5], it must be somewhat similar in form to *Orophocrinus pentangularis*, but

[1] 'Revision of the Palæocrinoidea,' Part III. 1885, p. 76.

[2] "Ueber einige neue und wenig bekannte Baltisch-Silurische Petrefacten." Mém. Acad. Imp. Sci. St. Pétersbourg, 1874, vii.e ser. tom. xxi. Mém. 11, p. 29.

[3] "On the Relations of *Hybocrinus*, *Baerocrinus*, and *Hybocystites*," Quart. Journ. Geol. Soc. 1882, vol. xxxviii. pp. 311, 312.

[4] "On the Crinoideæ of the Lower Silurian Rocks of Canada." Figures and Descriptions of Canadian Organic Remains, Decades Geol. Survey Canada, no. iv. 1859, pp. 18–21.

[5] *Loc. cit.* p. 27.

with larger deltoids which meet the radials along a horizontal suture at the level of the distal ends of the ambulacra. According to Schmidt the lower edge of the deltoid is marked by hydrospire-slits, which do not, however, extend down on to the upper edges of the radials beneath. The summit would thus resemble that of *Codaster trilobatus* if it were raised into a low dome and had triangular instead of rhombic deltoid plates (Pl. XIII. figs. 1, 3, 4). We should thus have no difficulty in placing *Blastoidocrinus* among the Blastoidea, though it would have to be assigned to an altogether separate family from the other members of the group, on account of the singular position of the radio-deltoid suture and the restriction of its hydrospires to the deltoid plates; but in neither of these characters would it offer an easy transition from the Blastoids to either Crinoids or Cystids. We must confess to some doubt, however, respecting the presence of its hydrospire-slits as described by Schmidt, for we have examined a deltoid plate of a Canadian specimen which appears to present the same structure; and this, as revealed by a section, is certainly nothing like the hydrospire-apparatus of a Blastoid. We are much rather inclined to think that it is a surface ornamentation, more especially as we have noticed a bifurcation of some of the ridges separating the supposed slits; and we know of no hydrospires, either in Blastoids or Cystids, in which such a structure occurs.

At the same time we are quite prepared, upon production of sufficient evidence, to accord *Blastoidocrinus* a place among the Blastoidea; and in some respects it would agree much more closely with the typical Blastoids than either *Astrocrinus* or *Eleutherocrinus*.

Regarding the group Blastoidea as a class of Echinoderms, we have now to consider how it may further be subdivided into orders and families. An attempt in this direction has already been made by S. A. Miller[1], who gives the group only ordinal value and divides it into three families, neither of which, however, does he define; and his names therefore have no real systematic value. His first family, Nucleocrinidæ, contains the single genus *Elæacrinus* or, as he prefers to call it, *Nucleocrinus*. In the second family, Pentremitidæ, are included the genera *Blastoidocrinus*, *Granatocrinus*, *Pentremites*, and *Troostocrinus*; while the third family, Stephanocrinidæ, embraces the four genera *Codaster*, *Codonites* (which is more correctly known as *Orophocrinus*), *Eleutherocrinus*, and *Stephanocrinus*. Three of these genera, however, represent widely different morphological types; and we cannot help thinking that if Mr. Miller had attempted to define the families which he established so easily, he would have had some difficulty in finding any characters common to *Eleutherocrinus* (Pl. XIX. figs. 4–6) and to *Codaster* (Pl. XII. figs. 1–6; Pl. XIII. figs. 1–3) other than those which are possessed by all Blastoidea.

It is not difficult to divide the class Blastoidea into two orders; for *Eleutherocrinus*, *Astrocrinus*, and *Pentephyllum* are very strikingly different from all the other types of Blastoids which were known to Roemer. These last have five equal and similar

[1] American Palæozoic Fossils, Catalogue of the Genera and Species, 2nd edition, 1883, p. 277.

radials and five ambulacra of the same character, which all meet at the peristome at equal angles (Pl. III. fig. 14; Pl. IV. fig. 17; Pl. V. fig. 23; Pl. VII. figs. 5, 14; Pl. IX. figs. 14, 15; Pl. XIII. figs. 1, 4; Pl. XV. figs. 2, 11). In the Astrocrinidæ, however, there is not only an abnormal development of the basals (Pl. XIX. fig. 5; Pl. XX. figs. 1, 8, 13, 15), but one radial and the corresponding ambulacrum are altogether different from their fellows (Pl. XIX. figs. 1, 4–6; Pl. XX. figs. 9, 13–20). The angle at which this azygos ambulacrum joins the peristome is different from the other four interambulacral angles, and its structure is altogether abnormal. The loss of a perfect radial symmetry which accompanies these peculiarities has led us to separate the typical Astrocrinidæ from the more regular Blastoids as an Order "Irregulares"; and with them we associate the problematical *Pentephyllum*, which closely resembles *Eleutherocrinus* in the distribution of its ambulacra (Pl. XVI. fig. 14; Pl. XIX. fig. 6), though it seems to have a tolerably symmetrical base (Pl. XVI. fig. 16). The basiradial sutures are not so clear as we could wish, but so far as we can judge from the only specimen known, which is merely an internal cast, there does not appear to be so much difference between the azygos radial and its fellows as in the typical Astrocrinidæ.

Taking then the Blastoids known to Roemer as constituting the Order "Regulares," we have now to see how they can be grouped into families. Roemer [1] proposed to make four different groups of the genus *Pentremites*, which he called respectively *Floreales*, *Elliptici*, *Truncati*, and *Clavati*. The type species in each of these groups is now generally regarded as representing a distinct genus, viz. *Pentremites*, *Granatocrinus*, *Pentremitidea*, and *Troostocrinus*; and this shows better than anything else could the truly natural character of Roemer's classification.

Pentremites and *Pentremitidea* are regarded by us as constituting, together with our new genus *Mesoblastus*, the family Pentremitidæ; while *Troostocrinus* and *Granatocrinus* are the types of the *Troostoblastidæ* and *Granatoblastidæ* respectively. *Codaster* and *Elæacrinus*, which were considered by Roemer to be altogether distinct genera, also appear to us to represent morphological types of family value; and in each case there are other more recently established genera which may fitly be placed in the same family.

All the six types of Blastoids, therefore, which were recognized by Roemer appear to us to be of generic value, while five of them are the leading genera of families.

Since the differences between his four groups of the genus *Pentremites* are principally founded "nach der äusseren Gestalt des Kelches und der Pseudambulacral-Felder im Besonderen," it is only to be expected that they should each contain certain species which the progress of knowledge has shown to belong to an altogether

[1] Archiv f. Naturgesch. Jahrg. xvii. 1851, Bd. i. p. 352.

different morphological type. Thus, for example, among the *Floreales*, of which *Pentremites Godoni* is the type (Pl. II. figs. 1–7), we find, though placed there with doubt, *Orophocrinus Puzos* (Pl. XIV. figs. 14, 15), and also *O. Orbignyanus* (Pl. XIV. figs. 16–18), and *Phænoschisma acutum* (Pl. XIV. figs. 10–12). Among the *Elliptici*, the type species of which is *Granatocrinus ellipticus* (Pl. VIII. figs. 16–19), we also find *Mesoblastus elongatus* (Pl. VIII. fig. 1), *M. angulatus* (Pl. VIII. figs. 7, 8), and *M. crenulatus*, though with doubt (Pl. IV. fig. 1); and likewise *Tricœlocrinus obliquatus* (Pl. XVIII. figs. 10–13), which Roemer described as "vielleicht Typus einer eigenen Familie." The *Truncati*, of which the type is *Pentremitidea Paillettei* (Pl. IV. figs. 8, 9), also include *Cryptoschisma Schulzi* (Pl. V. figs. 23–25). Besides these genera there are others, such as *Schizoblastus*, *Cryptoblastus*, *Metablastus*, and *Acentrotremites*, which we have been led to establish during the progress of our work. These have been principally founded, as was stated in the first of our preliminary papers [1], "on the morphology of the hydrospires and of their external openings, the so-called spiracles. We find that the structure and distribution of these organs, together with the arrangement of the various organs composing the ambulacra, present characters of much systematic value."

Hambach [2] has published some criticisms of our classification, a reply to which will be found in the 'Annals and Magazine of Natural History' for April, 1885. But at the same time he has also put forward a classification of his own, according to which "all described *Pentremites* (except those which belong to the genus *Codaster* or *Codonites*) can easily be distributed in either one or the other of these three divisions." It has been pointed out, however, that neither of these divisions affords any place for certain European Blastoids which have been described under the general name *Pentremites*, and have since been referred to *Orophocrinus* and *Phænoschisma*. The third of them is identical with *Granatocrinus*, as we had previously defined it. Hambach describes it as "comprising all those species in which the deltoid pieces are perforated, because the lancet-pieces do not reach far enough to the summit to enter into the composition of the spiracle-openings."

We are sorry to say that we do not altogether comprehend the meaning of this very teleological argument, and we do not think that Hambach would have used it had he been personally acquainted with the British species of *Granatocrinus*. It is quite true, as pointed out above, that the lancet-plates in three ambulacra of *G. Norwoodi*, as revealed by the casts, often terminate outside the circle of spiracles (Pl. VII. fig. 7); but this is by no means the case in the two posterior ambulacra or in *G. ellipticus*, *G. Derbiensis*, *G. M^cCyi*, and *G. campanulatus*, as we have explained above (Pl. VIII. fig. 17; Pl. IX. figs. 5, 14, 15; Pl. X. figs. 8, 10).

Hambach's first division of the forms hitherto referred to *Pentremites* "would com-

[1] Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 214.

[2] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, pp. 543–546.

prise all those species in which the horizontal portion of the deltoid piece is very narrow, the sinus to both sides in the deltoid and lancet pieces comparatively large, and so surrounded by the zigzag plicated integument that two of the so-formed openings appear externally only as one." In this division Hambach places all the typical Pentremites with broad ambulacra, such as *P. Godoni*, *P. sulcatus*, and *P. pyriformis*, and likewise two species of the Troostoblastidæ, viz. *Troostocrinus Reinwardti* and *Metablastus Wortheni*. One of its essential characters is the appearance externally of only five spiracular openings, as in the *Pentremites sulcatus* and *P. elongatus*, figured on Pl. I. figs. 4 and 10. But our other specimen of *P. elongatus*, which has divided spiracles (Pl. I. fig. 5), would have to be placed in Hambach's second division along with *Pentremites Burlingtonensis*, which appears to us to be little more than a variety of *P. Godoni*, as seen on Pl. I. fig. 2.

The spiracles of *Troostocrinus Reinwardti* are also imperfectly divided (Fig. VII. A on p. 112), while those of *Metablastus lineatus*, which Hambach admits to be an allied species, are very distinctly double, as seen in Pl. III. figs. 14, 15. Both these species would more properly find a place in Hambach's second division, in which the spiracular openings "have to remain separate, or, in other words, where we have ten distinctly visible openings." Besides *Pentremites Burlingtonensis* he places here the types which we distinguish as *Cryptoblastus melo*, *Schizoblastus Sayi*, and *Mesoblastus crenulatus*. We regard the last named as belonging to the Pentremitidæ, and place the two former genera in the same family as *Elæacrinus*, viz. the *Nucleoblastidæ*. Hambach appears to admit the morphological value of the generic type which is now usually known as *Granatocrinus*; but he sees "no good reason to separate the first division from the second because the number and relative position of these plates to each other remains the same." The plates to which he refers are the deltoids, which he describes as the principal cause of the differences in the spiracle-openings. As, however, the number and relative position of the deltoids *to each other* are the same in all Blastoids, and have absolutely nothing to do with the formation of the spiracles, we cannot see how they affect the question of the generic position of *Pentremites* and *Schizoblastus*.

Having laid down the general principle (from which we entirely dissent) that all described "Pentremites can easily be distributed in either one or the other of these three divisions," Hambach [1] proceeds to infer that "it is therefore impracticable to divide the genus *Pentremites* into four or five new genera." He devotes considerable space to explaining how certain species differ from others "mainly in the different length of the base and fork pieces," or "only in the different development of the calyx pieces." We quite agree with him that these characters, as he describes them, are altogether of minor importance. But they have another aspect altogether, which he has entirely overlooked, as will be evident from the fact that he says, "The

[1] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, p. 546.

difference between *Pentremites Pailleti* [Pl. IV. figs. 8–10] . . . . and *Woodmani* [Pl. XIX. figs. 13–16], ... show no greater divergences than there exist between . . . . *P. florealis* [Pl. II. fig. 3] . . . . and *abbreviatus* [Pl. II. fig. 4]" ! ! It is upon these characters, which he neglects, that we have founded the new generic types *Phænoschisma*, *Cryptoschisma*, *Schizoblastus*, *Cryptoblastus*, *Mesoblastus*, and *Metablastus* for the reception of species which were formerly known only under the very general name *Pentremites*. Say's name has had to undergo the same restriction of its meaning as was the case with the generic names *Cyathocrinus*, *Actinocrinus*, and *Poteriocrinus* of Miller. A very large number of species have been described under each of these names, and they have been found to fall into certain very definite groups, for one of which Miller's original designation has been retained.

The genus *Pentremites* began to undergo the same process when D'Orbigny established *Pentremitidea* in 1849. In the course of the next two years *Olivanites* and *Elæacrinus* were proposed by Troost and Roemer for the *Pentremites Verneuili* of 1841, a species, by the way, which is nowhere mentioned by Hambach. *Granatocrinus*, though proposed in 1850, was not formally adopted by Hall till 1862. *Orophocrinus* followed in 1864, *Troostocrinus* in 1865, and *Tricœlocrinus* in 1868. *Schizoblastus* and *Phænoschisma* were proposed by ourselves in 1882; and we shall now define four more generic types for the reception of species which were first referred to *Pentremites*, viz. *Cryptoschisma*, *Mesoblastus*, *Cryptoblastus*, and *Metablastus*. We believe that our reasons for this course will meet with the approval of scientific palæontologists, though we do not suppose for a moment that they will commend themselves to Hambach.

At the same time we have been very much impressed by the remarkable manner in which some of the different generic types are linked together. Each of the three irregular genera is very well defined; while the same may be said of *Acentrotremites*, with its spiracles on the radio-deltoid suture (Pl. XIII. figs. 18, 19), and also of *Codaster*, which has no hydrospires in the anal interradius (Pl. XIII. figs. 1, 4). It is perhaps also true of *Granatocrinus*, with its deltoid perforated by the single spiracle. But an abnormal specimen, in which the hydrospire-canals of one interradius open separately (Pl. VII. fig. 13), is the first indication of a transition towards *Heteroblastus* (Pl. VI. figs. 3, 4) and thence to *Cryptoblastus* (Pl. VII. figs. 14, 15), which resembles *Granatocrinus* in its external form and in the possession of an hydrospire-plate. On the other hand, the presence of this plate distinguishes *Cryptoblastus* from *Schizoblastus*, which has spiracles closely similar to those of the former genus (Pl. III. figs. 1–3); and the two Irish species of *Schizoblastus* further resemble *Cryptoblastus* in the confluence of the anus with the two posterior spiracles (Pl. VIII. fig. 9; Pl. XVI. fig. 12), a character which does not occur in the American species of the genus (Pl. III. figs. 1–3; Pl. VI. fig. 16). In this latter respect, and also in the absence of an hydrospire-plate, *Schizoblastus Sayi* approaches *Elæacrinus*

(Pl. XVIII. figs. 16, 19), and the presence of an anal plate, which is the distinguishing character of the latter genus, is as it were foreshadowed in the superficial markings on the other deltoids of this type and on those of *Schizoblastus Sayi*, as we have pointed out on p. 35. There is also a considerable resemblance in the structure of the spiracles between this species and *Metablastus lineatus*, different as they are in external form; while they both possess a triply perforate lancet-piece as shown on Pl. XVII. figs. 1, 18.

Metablastus itself passes rather gradually into *Tricœlocrinus*. The extreme forms, such as *M. lineatus* and *Tricœlocrinus Woodmani* (Pl. III. figs. 14, 15; Pl. XIX. figs. 13, 15), are very different; but they are closely linked together by forms like Hall's *Pentremites* (*Metablastus*) *Wortheni*, the *Tricœlocrinus obliquatus* of Meek and Worthen, and our own *Metablastus Meekianus* (Pl. XVI. figs. 17, 18). It is possible that both in the last-named, and also in the *Pentremites Grosvenori* of Shumard, the deltoids appear in a side view of the calyx as in the Pentremitidæ; while in *Troostocrinus Reinwardti* one deltoid only, that of the anal side, is thus exposed. The type which Hambach described as *Pentremites clavatus* has much the form of a *Metablastus*, though we should not like to refer it to this type, as the ambulacra are said to join one another above the deltoid ridges. It is very like our *Metablastus Hispanicus* (Pl. V. fig. 21), and gives us an excellent transition between *M. lineatus* or *M. Wortheni* and some forms of *Pentremitidea* (Pl. V. fig. 17; Pl. XIV. fig. 13), and also of those species of *Pentremites* which show but little of the deltoids externally, such as the *P. pyriformis* represented on our Pl. II. fig. 30, or Hambach's other species *P. gemmiformis*.

The link between *Pentremites* and *Pentremitidea* is naturally very close, as will be evident on comparison of our figures of *Pentremites conoideus* and *P. elongatus* (Pl. II. figs. 15, 16) with that of *Pentremitidea*? *leda* on Pl. V. fig. 12. The extremely narrow ambulacra of the last-mentioned type have induced us to refer it to *Pentremitidea*, and there appear to be some other good species of this genus which also have the deltoids visible on the exterior of the calyx.

If *Pentremitidea*? *leda* had an hydrospire-plate and its spiracles more distinctly double, it would be almost indistinguishable from *Mesoblastus Sowerbii* (Pl. V. figs. 12–14; Pl. VI. figs. 12–14); and this type again approaches rather closely to some forms of *Schizoblastus* which differ from it in the absence of an hydrospire plate. The slit-like spiracles of *Schizoblastus* are simply portions of the proximal ends of the radial sinus which remain open between the narrow ambulacra and the sides of the deltoids. Almost the same may be said of *Metablastus lineatus* (Pl. III. figs. 14, 15), and there is not much difference between the spiracles of this type and those of such a form as *Orophocrinus verus* (Pl. XV. fig. 3; Pl. XVI. fig. 10), unlike as the two calyces are in their general appearance. *Orophocrinus verus* is the nearest approach to *O. stelliformis* on the one hand, and on the other it is closely related to

Phænoschisma. The hydrospire-cleft is rather less constricted in *O. pentangularis* (compare figs. 4 & 10 on Pl. XV.), and from the latter type it is an easy transition to *O. Puzos* and *O. Orbignyanus* (Pl. XIV. figs. 14–18). But for the relatively large size of the deltoids and their appearance externally above the truncated radial limbs there is really nothing to separate these two species from *Phænoschisma*—*P. Archiaci*, perhaps, being the type which approaches them most closely (Pl. XII. fig. 10). *Codaster* only differs from *Phænoschisma* in the absence of hydrospires in the posterior interradius (Pl. XII. figs. 1, 4; Pl. XIII. figs. 1, 4); while *Phænoschisma caryophyllatum* would be a *Cryptoschisma* if it had a broader summit and its ambulacra were a little wider so as to completely conceal the hydrospire-slits (Pl. V. figs. 23, 24; Pl. XIII. fig. 20; Pl. XIV. figs. 1–4). But there is no sort of resemblance between *Cryptoschisma* and *Phænoschisma nobile* (Pl. XI. figs. 1–4), with which *P. caryophyllatum* is linked by several intermediate forms.

The principal resemblances and differences between the various genera of the Pentremitidæ, Troostoblastidæ, Nucleoblastidæ, and *Orophocrinus* are conveniently shown in the following Table.

	Pentremites.	Pentremitidea.	Mesoblastus.	Troostocrinus.	Metablastus.	Orophocrinus.	Schizoblastus.	Elæacrinus.	Cryptoblastus.	Acentrotremites.
Deltoids visible on the exterior of the calyx.	*	In *P.* ? *leda.*	*	On anal side only.	....	*	*	*	*	*
No hydrospire-pores at their sides	..	....	..	....	..	..	..	..	*	*
Anal plate	..	....	..	....	..	..	..	*	..	..
Ambulacra have an under lancet-plate.	*	....	..	....	..	*	..	..	..	..
An hydrospire-plate present..........	..	....	*	....	..	..	..	..	*	..
Spiracles on radio-deltoid sutures......	..	....	..	....	..	In some forms.	..	..	..	*
Spiracles distinctly in pairs	..	....	..	Variable.	*	*	*	*	*	*
Posterior spiracles fused with anus ...	*	*	*	*	..	..	Only in the two Irish species.	..	*	..

Closely related, however, as are most of the regular Blastoids to one another, our morphological inquiries have led us to believe that they represent more generic types than have hitherto been recognized. On the other hand, we have come to the conclusion that the variations of individual specific forms are unusually extensive, and

that the number of so-called species of *Pentremites* would be very greatly reduced if they were all subjected to a critical examination which was based on the comparison of a large amount of material. In one or two cases this has been, to some extent, possible for us. Thus, for example, we have a striking series of forms which we refer to *Pentremites Godoni* (Pl. II. figs. 1–7), among them being *Pentremites abbreviatus*, Hambach (fig. 4). *Pentremites symmetricus*, Hall, seems in like manner to link together several varieties of Say's older species *P. pyriformis* (Pl. II. figs. 24–30); while, following the lead of Prof. R. P. Whitfield, we cannot regard Hall's *P. conoideus* and *P. Koninckanus* as distinct species (Pl. II. figs. 16–23). On the same plate are shown two very dissimilar forms of *P. elongatus* (figs. 14, 15) and four varieties of *Granatocrinus Norwoodi* which pass very gradually into one another (figs. 32–35). A similar variation occurs in the British *G. ellipticus* (Pl. VIII. figs. 16–19; Pl. X. fig. 16).

From these few examples we may not unfairly conclude that a revision by competent hands of the host of different species of *Pentremites* which have been described in America would reduce a great proportion of them to the rank of synonyms. It is equally probable that a similar abundance of material would render the same course necessary in the case of the European species of *Pentremitidea* described by ourselves.

CHAPTER VII.

THE GEOLOGICAL AND GEOGRAPHICAL DISTRIBUTION OF THE BLASTOIDEA.

We have no certain evidence of the existence of true Blastoidea anterior to the Upper Silurian period. For we much doubt, as we have explained in the previous Chapter, whether the problematical *Blastoidocrinus* from the Lower Silurian of Canada and Russia can properly be referred to this group.

It is curious that all the known Blastoids of the Upper Silurian period are confined to American strata. None have been found in the Wenlock Limestone of Britain, though representatives of two, or probably of three, genera occur in the Niagara Group, which is the corresponding formation in America. One of these is *Codaster*, if, as we believe, the *Codaster pulchellus* of Miller and Dyer[1] from Waldron, Indiana, is rightly named. An internal cast from this horizon, which has been described by Hall and Whitfield[2], from Ohio, together with an imperfect specimen figured by Hall[3] from Indiana, appear to us to be referable to the Troostoblastidæ, though we cannot venture to give them generic names. In the Niagara Group of Tennessee, however, well-preserved examples of *Troostocrinus Reinwardti* are not uncommon.

We are not acquainted with the presence of Blastoids in the Upper Silurian rocks of any other part of the world than North America. This is the more striking when we recollect the great development of Crinoid life which took place during the Wenlock Period in Europe, especially as represented by the Wenlock Series of England and of the island of Gotland.

The Devonian rocks of the British Islands have yielded but the scantiest evidence of Blastoid life, and we are not in a position to affirm with certainty the generic relations of the specimens hitherto found. The late Prof. J. Phillips[4] described one species from the Pilton Group (Upper Devonian) of North Devon, which he referred to *Pentremites ovalis*, Goldfuss. We have not been able to trace this specimen, and

[1] Contributions to Palæontology. Journ. Cincinnati Soc. Nat. Hist. 1878, vol. i. no. 1. p. 35, pl. 2. fig. 13. See also Hall, in Collett's 11th Ann. Report Dept. Geol. & Nat. Hist. Indiana for 1881 [1882], p. 280, pl. 15. figs. 8–10.

[2] *Pentremites subcylindrica* (Ohio Geol. Report, 1875, vol. ii. part 2, p. 129, pl. vi. fig. 13).

[3] *Codaster pentalobus* (Collett's 11th Report, *loc. cit.* p. 280, pl. 15. fig. 16).

[4] Pal. Foss. Cornw., Devon, and W. Somerset, 1841, p. 29, t. 14. f. 40.

it may quite as well be any other species as that to which Phillips considered it to be related. The Rev. G. F. Whidborne has since discovered an imperfect specimen in the Middle Devonian of South Devon [1], which he has been kind enough to allow us to examine (Pl. IV. fig. 7). It may perhaps be a *Pentremitidea.*

A fragmentary specimen from the Torbay Limestone (Middle Devonian) of Barton, S. Devon, is in the collection of J. E. Lee, Esq., F.G.S. It is too ill preserved for description, but has much the aspect of a *Troostocrinus* or *Metablastus.*

The Lower Devonian (Grès de Gahard) of France has yielded a peculiar form, which was named by M. Munier-Chalmas *Belemnocrinus Cottaldi* [2], and has been since described more fully by Œhlert as *Belocrinus Cottaldi* [3]. We have already expressed the opinion that this is only the elongated basal cup of a *Troostocrinus* or *Pentremitidea*; and, having been enabled to examine specimens of the type by the kindness of M. Munier-Chalmas, we are inclined to refer it to the Troostoblastidæ. But in the absence of the upper part of the calyx, we cannot say definitely whether it is a *Troostocrinus* or a *Metablastus*, though we think the latter most probable.

In Belgium, strange to say, the Lower Devonian rocks have again yielded a solitary Blastoid. Dr. Julien Fraipont has described a species from the top of the Rhénan Series, or Lower Devonian, under the name of *Pentremites Fraiponti*, Dewalque [4]. We are indebted to Professor G. Dewalque, of Liège, for the loan of the original type of this species, which we believe to be a *Pentremitidea* closely allied to *P. Efelensis* (Pl. V. figs. 1, 2). The inequality of the radials, on which Fraipont laid much stress, appears to us to be due to the crushed state of the specimen.

The great centre of Blastoid life during Devonian times in Europe appears to have been in the north of Spain. Four genera are represented in the Lower Devonian of the Asturias and of the Province of Leon, viz. *Pentremitidea*, *Phænoschisma*, *Metablastus* (or *Troostocrinus*), and *Cryptoschisma.*

The first-named genus is represented by several species, one (*P. clavata*, Schultze, sp.) being common both to the Spanish and to the Eifel beds. *Phænoschisma* is represented by three species, one of which, *P. nobile*, nobis, is the largest known form of the genus (Pl. XI. fig. 1), while no other *Cryptoschisma* is known. In other words, we have in the Spanish beds the first appearance of two genera, *Phænoschisma* and *Cryptoschisma*, the latter being peculiar to them, either the continued existence of *Troostocrinus* or its replacement by *Metablastus*, and the great development attained by *Pentremitidea.*

The two horizons represented by these fossils, the Calcaire de Ferroñes and the Sabero deposits, are probably of nearly the same geological age. They belong, accor-

[1] Geol. Mag. 1881, vol. viii. p. 288.

[2] Journ. Conchyl. 1876, vol. xvi. p. 105.

[3] Bull. Soc. Géol. France, 1882, vol. x. p. 362, t. 9. f. 3, *a–e.*

[4] Ann. Soc. Géol. Belgique, 1884, vol. xi. p. 114.

ding to M. C. Barrois [1], the most recent writer on the subject, to the Lower Devonian series; but they are situated at a relatively higher level in it than the Grès de Gahard in France, though probably at nearly the same horizon as *Pentremitidea Fraiponti* in Belgium (Coblencien supérieur).

It is possible that another genus may occur in these Spanish beds. According to Roemer [2], de Verneuil's collection from the Asturias contained a Blastoid resembling *Orophocrinus verus*, Cumbld. sp. (=*Pentatrematites inflata*, G. B. Sby.). This is to a certain extent borne out by an illustration given by Don Lucas Mallada [3], who figures this identical species as a Spanish Devonian Blastoid. Unfortunately, however, his figure is only an exact reproduction of that given by Phillips of the British Carboniferous fossil [4]. We have been unable to obtain any information about de Verneuil's collection, and can therefore offer no opinion on the subject.

The Devonian rocks of the Eifel and Rhine have, with any certainty, yielded only one genus, *Pentremitidea.* Goldfuss described what appears to be a veritable *Pentremites* from the slaty beds below the Carboniferous Limestone near Dusseldorf [5]; but we have reason to believe that this species is really of Carboniferous age. *Pentremitidea* is wholly confined, so far as we can ascertain, to the Middle Devonian and to two horizons therein, viz. the Eifeler-Kalk of the Eifel [6], and the Stringocephalen-Kalk of Nassau. Of the six species at present known, five are peculiar to the former locality and one to the latter. One of the five is likewise met with in Spain.

A great increase in Blastoid life is displayed in the Devonian rocks of the North-American continent. There is evidence of four or possibly of six genera, containing amongst them a large number of species. Two genera are peculiar both to the country and to the formation, and do not pass upwards into the Carboniferous, viz. *Eleutherocrinus* and *Elæacrinus.*

Each of these is represented both in the Upper Helderberg or Corniferous Group of the Lower Devonian, and in the Hamilton Group of the Upper (or ? Middle) Devonian. *Eleutherocrinus* has a species common to both horizons, and a second one in the Hamilton Series; while there are three species of *Elæacrinus* in the Lower, and five in the Upper Devonian, none of which last occur in the lower beds.

Schizoblastus, a closely allied genus to *Elæacrinus*, also seems to make its first appearance in the Upper Devonian, being represented by one of the two specimens described by Shumard [7] from the Chemung Group at Providence, Missouri, under the

[1] Mém. Soc. Géol. Nord, 1882, tome ii., Mém. 2, p. 518; Compt. Rend. Assoc. Franç. 1883 [1884], p. 448.

[2] Archiv f. Naturgesch., 1851, Jahrg. xvii. Bd. i. p. 375.

[3] Bol. Com. Mapa Geol. España, 1877, tomo iv. lám. 12. f. 11.

[4] Ill. Geol. York. pt. 2, 1836, t. 3. f. 3.

[5] Petrefacta Germaniæ, Theil i. p. 161, t. 50.

[6] Contrary to most writers, Barrois considers this as a portion of the Lower Devonian.

[7] Swallow's 1st and 2nd Missouri Geol. Report, 1885, t. B.

name of *Pentremites Roemeri*, which was subsequently changed to *Granatocrinus Missouriensis*[1]. Mr. S. A. Miller tells us, however, that this species really belongs to the middle or upper part of the Subcarboniferous; and we must therefore leave the existence of *Schizoblastus* as a Devonian genus in some doubt.

The same remarks apply to *Granatocrinus* as represented by *G. Roemeri*, Shumard[2]; though Hall[3] has described three species of *Pentremites* from the Hamilton Group, any one of which may really belong to this genus, viz. *P. calyce*, *P. lycorias*, and *P. Whitei.* But it is equally possible that they should be referred to *Mesoblastus* or to *Pentremitidea.* An unquestionable example of the latter genus has, however, been recently described by Barris[4] from the Hamilton Group of Michigan; and Hall's *Pentremites leda* (Pl. V. figs. 12–14) is probably an aberrant species of the same generic type.

We know of no Troostoblastidæ of Devonian age in America, though the family is represented by single species in the Devonian of Britain, France, and Spain; but we cannot refer them for certain to *Metablastus* or to *Troostocrinus.* In our notes[5] on the latter genus, published a few years ago, we included *Pentremites subtruncatus*, Hall, from the Hamilton Group of Iowa, as a *Troostocrinus.* We were probably in error in this reference, for this species now appears to us to be more nearly allied to *Codaster* or *Phænoschisma.* We have no certain knowledge that the latter genus occurs at all in the American Devonian, though we have seen some undescribed Carboniferous species; while *Codaster* is abundant both in the Lower and in the Upper Devonian, though it is only known as a Carboniferous genus in Europe.

Taking the Blastoids of the Devonian system as a whole, we find that they present several points of interest.

(1) The number of genera was largely increased at the close of the Silurian period, all the families being represented in the Devonian.

(2) The genus *Pentremites*, which is the type of the class, has, however, not yet made its appearance.

(3) The Silurian Troostoblastidæ disappear in the American Devonian Series, but are well represented in Europe.

(4) The appearance of *Pentremitidea* on both sides of the Atlantic, though it attains a much greater development in the European area, and is not known in America below the Upper Devonian.

[1] Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 375. In our list of species of *Schizoblastus* we called this species *Pentremites.* We should have written *Granatocrinus*, the name eventually given to it by Shumard (see Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 247).

[2] As restricted in Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 376.

[3] Fifteenth Annual Report New York State Cab. Nat. Hist. 1862, pp. 150 & 151.

[4] Proc. Davenport Acad. Nat. Sci. 1885, vol. iv. p. 93, pl. i. fig. 4.

[5] Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 249.

(5) The appearance of other genera which are peculiar to each area respectively, viz. :—*Cryptoschisma* and *Phænoschisma* in Europe ; *Codaster*, *Elæacrinus*, *Eleutherocrinus*, and perhaps also *Granatocrinus* and *Schizoblastus* in America. Three of these, *Cryptoschisma*, *Elæacrinus*, and *Eleutherocrinus*, are exclusively Devonian genera. *Phænoschisma* passes up into the Carboniferous of Belgium, England, Scotland, and America ; while two at least of the other three types occur abundantly in the Carboniferous of both Britain and America.

(6) The Devonian Blastoids of America are slightly more numerous, both in genera and in species, than those of the European area, though not greatly so.

The Carboniferous rocks of the British Islands are particularly rich in Blastoidea, no less than ten genera being therein represented. Only one of these, *Phænoschisma*, is also found in the European Devonian, whilst from American rocks of that age there pass up *Codaster*, and also *Schizoblastus* and *Granatocrinus* (*fide* Shumard). In addition to these, there are the peculiarly British genera *Acentrotremites*, *Pentephyllum*, and *Astrocrinus*. *Phænoschisma*, *Orophocrinus*, and *Mesoblastus* are common to America, Britain, and Belgium. *Heteroblastus* is perhaps found in America, while *Pentremites*, strange to say, is not a British genus at all, its place, as regards the relative abundance of species, being apparently taken by *Granatocrinus* and *Mesoblastus* together.

The whole of the genera mentioned are confined to the Carboniferous Limestone, and we know of no trace of Blastoidea from the Lower Carboniferous (or Calciferous Sandstone Series), much less from any of the marine bands of the Coal-Measures.

Pentremitidea does not occur in the Carboniferous rocks, and it appears to have died out at the close of the Devonian period ; though *Phænoschisma* is represented by two of the six described species Two species of *Schizoblastus* have been met with in the Irish Limestones, but it is not known in the English beds, which contain, however, the allied genus *Acentrotremites*. *Granatocrinus*, on the other hand, has increased in the number of species, and may be looked upon as the typical British genus, being individually much more abundant than *Mesoblastus*, of which there are also five British species. *Orophocrinus* has three representatives in this country, and is of interest from its extended geographical range. *Codaster*, although not rich in species, is a genus of importance, from the large number of individuals which occur in certain localities. The curious little irregular genus *Astrocrinus*, the surviving representative of *Eleutherocrinus* from the Devonian of America, has only been met with, so far as we are aware, in the Carboniferous Limestone Series of England and Scotland ; while *Pentephyllum* is peculiar to the same horizon in Ireland. We have not met with any evidence of either *Troostocrinus*, *Tricœlocrinus*, or *Metablastus* in the British Carboniferous rocks.

Little remains to be said of the Blastoidea met with in the Continental Carboniferous

rocks. In Belgium the Upper Carboniferous Shale of Tournay has yielded *Orophocrinus*, *Phænoschisma*, and *Mesoblastus*. As regards Germany, we have pointed out above that we suspect *Pentremites ovalis*, Goldfuss, to be a Carboniferous and not a Devonian species.

In North America the series of rocks which we call Carboniferous Limestone are by American geologists termed Subcarboniferous. According to Dana [1], the series is divided in the Interior Continental Basin into the following Groups, proceeding from above downwards:—

1. Chester Group . . . . { Pentremital Limestone. Upper Archimedes, or Kaskaskia Limestone.
2. St. Louis Group . . . . { Warsaw Limestone. Spergen Hill beds.
3. Keokuk Group.
4. Burlington Group.
5. Kinderhook Group . . . . . . { Choteau Limestone. Goniatite Limestone.

Ten or possibly even twelve genera are known to exist, distributed throughout the above groups, viz.—*Pentremites*, *Mesoblastus*, *Granatocrinus*, *Schizoblastus*, *Cryptoblastus*, *Codaster*, *Phænoschisma*, *Orophocrinus*, *Tricœlocrinus*, *Metablastus*, and perhaps *Troostocrinus* (*T.* ? *Grosvenori*), and *Heteroblastus* (*H.* ? *cornutus*). *Pentremites* is very largely represented, but we cannot give even an approximate idea of the number of species, from the confused state of their synonymy. The earliest representatives of the genus are two species in the Upper Burlington Limestone. None are known from the Keokuk, and only two or three in the St. Louis Group; but there must be at least fifteen species in the Chester Limestone, after a liberal allowance has been made for synonyms.

Definite information is much needed with respect to the American species of *Granatocrinus*. The typical species, *G. Norwoodi*, occurs low down in the series, in the Burlington Group, together with its variety *fimbriatus*. The species from the St. Louis Group, which is generally known as *Granatocrinus granulatus*, Roem., sp., may possibly belong to this genus, though we doubt it; for we are by no means clear that the deltoids are really perforated by the spiracles (Pl. VI. fig. 22). We would say the same of most, if not all, of the other species which have been referred to *Granatocrinus*. Many of them seem to us to belong to *Schizoblastus*. *G. melo* is the type of our *Cryptoblastus*, while *G. glaber* is a *Mesoblastus*; and there may perhaps be other American species which should be referred to one of these generic

[1] Man. Geology, 3rd edit. p. 294.

types, while we strongly suspect that *G. cornutus* is a representative of our new type *Heteroblastus* (Pl. VI. fig. 1).

Schizoblastus is fairly abundant in the Burlington Group, and, so far as our information goes, one species occurs in three of the other subdivisions of the American Carboniferous Limestone, the Chester Group having none. *Metablastus* is represented in all but the lowest, and *Pentremites Grosvenori*, Shumard, is possibly congeneric with the Silurian *Troostocrinus Reinwardti*. The allied genus *Tricœlocrinus*, however, is peculiar to the Keokuk and St. Louis Groups.

Our knowledge of the American Carboniferous Codasteridæ is limited to four species in the Burlington Limestone and two undescribed species of *Phœnoschisma* from New Mexico. Two of these four belong to *Orophocrinus*, while the other two may be either *Codaster* or *Phœnoschisma*; but in neither case have we any certain information respecting the presence or absence of hydrospires in the anal interradius, though we suspect that *Codaster Whitei*, Hall, is rightly so named. The internal cast described by Miller [1] from the Keokuk Group, under the name of *Codaster gratiosus*, seems to have no indication of the presence of any external hydrospire-slits, and cannot therefore be referred to this genus.

The American Carboniferous rocks thus contain ten distinct genera, and two doubtful ones, as against the ten well-defined generic types which occur in Britain. *Pentremites* and perhaps *Schizoblastus* are most abundant in America, *Granatocrinus* and *Mesoblastus* in Britain; but they are far more rare, both specifically and individually, than the two leading American genera. The Troostoblastidæ, which are fairly common in the American Carboniferous, are absent in Britain; while, on the other hand, there are three Devonian species in Europe, but none in America.

It will be seen from the stratigraphical list on pp. 137–144 that the distribution of the various species of Blastoids is very limited both in Space and in Time. A few species appear to be common to the Upper and Lower Devonian of America; but each of the great divisions of the Subcarboniferous in the Mississippi valley seems to have its own particular types. No Blastoid occurs on both sides of the Atlantic; one species is common to the Devonian of Spain and Germany; and another to the Carboniferous Limestone of Britain and Belgium. But with these exceptions the range of individual specific types is very limited indeed.

The following Table gives a convenient *résumé* of the facts detailed above. It does not include the problematical *Blastoidocrinus* from the Lower Silurian of Canada and Russia.

[1] "Description of two new species from the Niagara Group and five from the Keokuk Group." Journ. Cincinnati Soc. Nat. Hist. 1880, vol. ii. p. 215, pl. xv. fig. 5.

TABLE showing the Distribution of the Genera of the Blastoidea in Space and Time.

PERIOD	UPPER SILURIAN.	DEVONIAN.						CARBONIFEROUS.			
COUNTRY ...	America.	America.	Britain.	Belgium.	Germany.	France.	Spain.	America.	Britain.	Belgium.	Germany.
Order REGULARES, *E. & C.*											
PENTREMITIDÆ, *d'Orb.*											
Pentremites, *Say*								*			?
Pentremitidea, *d'Orb.*		*	?	*	*		*				
Mesoblastus, *E. & C.*								*	*	*	
TROOSTOBLASTIDÆ, *E. & C.*											
Troostocrinus, *Shumard*	*		?			?	?	?			
Metablastus, *E. & C.*			?			?	?	*			
Tricœlocrinus, *M. & W.*								*			
NUCLEOBLASTIDÆ, *E. & C.*											
Elæacrinus, *Roemer*		*									
Schizoblastus, *E. & C.*		?						*	*		
Cryptoblastus, *E. & C.*								*			
Acentrotremites, *E. & C.*									*		
GRANATOBLASTIDÆ, *E. & C.*											
Granatocrinus, *Troost*		?						*	*		
Heteroblastus, *E. & C.*								*	*		
CODASTERIDÆ, *E. & C.*											
Codaster, *McCoy*	*	*						*	*		
Phænoschisma, *E. & C.*							*	?	*	*	
Orophocrinus, *v. Seebach*								*	*	*	
Cryptoschisma, *E. & C.*							*				
Order IRREGULARES, *E. & C.*											
ASTROCRINIDÆ, *T. & T. Austin.*											
Astrocrinus, *T. & T. Austin*									*		
Eleutherocrinus, *Shum. & Yand.*		*									
Pentephyllum, *Haughton*									*		

A STRATIGRAPHICAL LIST OF ALL KNOWN BLASTOIDS, ARRANGED GEOGRAPHICALLY.

This list does not include some undescribed American species which we have seen, and is not to be regarded as anything more than a table of the results of our own investigations. These are necessarily incomplete in the case of many foreign Blastoids, as regards both systematic and stratigraphical position. The names of all species with which we are personally acquainted are marked with an asterisk *.

We have inserted a ? after a generic name when we are not quite certain as to the systematic position of the species; but the name employed is the one which seems to us to be the most suitable.

In those cases where the want of material or of adequate figures has entirely prevented us from determining the generic position of a species, we have put the original generic name within square brackets [ ].

UPPER SILURIAN.

NORTH AMERICA.

Niagara Group = Wenlock Limestone.

Troostoblastidæ.

*Troostocrinus Reinwardti, *Troost,* sp.
[Pentremites] subcylindricus, *Hall & Whitfield.*
[Codaster] pentalobus, *Hall.*

Codasteridæ.

Codaster ? pulchellus, *Miller & Dyer.*

DEVONIAN.

NORTH AMERICA.

A. Lower Devonian.

Upper Helderberg or Corniferous Group.

Nucleoblastidæ.

*Elæacrinus angularis, *Lyon,* sp.
Elæacrinus Conradi[1], *Hall,* sp.
*Elæacrinus Verneuili, *Troost,* sp.[2]
*Elæacrinus Verneuili, var. pomum, *E. & C.,* var.

[1] Possibly only a variety of *E. Verneuili.*

[2] Shumard (Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 369) includes with this species *Pentremites carioides,* Owen, a form we are not acquainted with.

Codasteridæ.

Codaster alternatus[1], *Lyon.*
*Codaster alternatus, var. elongatus, *Wachsmuth,* var.
Codaster Americanus[2], *Shumard.*
*Codaster pyramidatus, *Shumard.*

Astrocrinidæ.

*Eleutherocrinus Cassedayi, *Shumard & Yandell.*

Genus undetermined :—

[Pentremites] striatus, *Hall, MS.*

B. Upper Devonian.

(i) **Hamilton Group.**

Pentremitidæ.

Pentremitidea Americana, *Barris.*
*Pentremitidea? leda, *Hall,* sp.

Nucleoblastidæ.

Elæacrinus elegans[3], *Hall,* sp.
*Elæacrinus Canadensis[3], *Montgomery,* sp.
Elæacrinus lucina, *Hall,* sp.
Elæacrinus meloniformis, *Barris.*
*Elæacrinus obovatus, *Barris.*

Codasteridæ.

Codaster alternatus, *Lyon.*
*Codaster alternatus, var. elongatus, *Wachsmuth,* var.
*Codaster gracilis, *Wachsmuth,* sp.
*Codaster Hindei[4], *E. & C.*
Codaster? subtruncatus, *Hall,* sp.

Astrocrinidæ.

*Eleutherocrinus Cassedayi, *Shumard & Yandell.*
Eleutherocrinus Whitfieldi, *Hall.*

Genera undetermined :—

[Pentremites] calyce, *Hall.*
[Pentremites] lycorias, *Hall.*
[Pentremites] Maia, *Hall.*
[Pentremites] Whitei, *Hall.*

[1] We have seen no specimens from the Upper Helderberg ; but it seems to be the one mentioned by Lyon.
[2] Possibly only a variety of *C. pyramidatus.*
[3] Possibly identical with *Nucleocrinus Halli,* Vanuxem, MS.
[4] Possibly identical with *C. Canadensis,* Billings, MS.

(ii) **Chemung Group.** (*Fide* Shumard.)

Nucleoblastidæ.

Schizoblastus ? Missouriensis, *Shumard,* sp.

Genus undetermined :—

[Granatocrinus] Roemeri, *Shumard.*

GREAT BRITAIN.

A. Middle Devonian.

Plymouth Limestone.

Pentremitidæ.

*Pentremitidea ? Whidbornei, *E. & C.*

Torbay Limestone.

Troostoblastidæ.

*Metablastus, sp.

B. Upper Devonian.

Pilton Group.

Genus undetermined :—

[Pentremites] ovalis, *Phillips* (*non Goldfuss*).

GERMANY.

Middle Devonian.

Givétien.

Pentremitidæ.

Pentremitidea acutangula, *Schultze,* sp.
*Pentremitidea clavata, *Schultze,* sp.
*Pentremitidea Eifelensis, *Roemer,* sp.
*Pentremitidea Roemeri, *E. & C.*
*Pentremitidea similis, *E. & C.*

Genus undetermined :—

[Pentatrematites] gracilis [1], *Steininger.*
[Pentatrematites] plana [2], *G. & F. Sandberger.*

BELGIUM.

Lower Devonian.

Schistes de Bure. (Transition-beds between the Rhénan and the Eifelien.)

Pentremitidæ.

*Pentremitidea Fraiponti, *Dewalque,* sp.

[1] Possibly identical with *Pentremitidea Eifelensis.*

[2] This species occurs in Nassau, while the others are all from the Eifel district.

FRANCE.

LOWER DEVONIAN.

Taunusien. Grès de Gahard.

Troostoblastidæ.

*Metablastus? Cottaldi, *Munier-Chalmas*, sp.

SPAIN.

LOWER DEVONIAN.

(i) **Coblencien supérieur.** Calcaire de Ferroñes.

Pentremitidæ.

*Pentremitidea Paillettei, *de Verneuil*, sp.

Codasteridæ.

*Cryptoschisma Schulzi, *d'Archiac & de Verneuil*, sp.

(ii) **Eifelien.** (*Fide* Barrois.) Calcaire d'Arnao.

Pentremitidæ.

*Pentremitidea angulata, *E. & C.*
*Pentremitidea clavata, *Schultze*, sp.
*Pentremitidea clavata, var. Schultzei, *E. & C.*, var.
*Pentremitidea Gilbertsoni, *E. & C.*
*Pentremitidea Lusitanica, *E. & C.*
*Pentremitidea Malladai, *E. & C.*
*Pentremitidea Paillettei, *de Verneuil*, sp.
*Pentremitidea Wachsmuthi, *E. & C.*

Troostoblastidæ.

*Metablastus? Hispanicus, *E. & C.*

Codasteridæ.

*Phænoschisma Archiaci, *E. & C.*
*Phænoschisma nobile, *E. & C.*
*Phænoschisma Verneuili, *E. & C.*
*Cryptoschisma Schulzi, *d'Archiac & de Verneuil*, sp.

CARBONIFEROUS LIMESTONE.

(The SUBCARBONIFEROUS of American geologists.)

BRITAIN.

Pentremitidæ.

*Mesoblastus angulatus, *Sowerby*, sp.
*Mesoblastus elongatus[1], *Cumberland*, sp.
*Mesoblastus giganteus, *E. & C.*
*Mesoblastus Rofei, *E. & C.*
*Mesoblastus Sowerbii, *E. & C.*

[1] Identical with *Pentatrematites oblonga*, G. B. Sowerby.

Nucleoblastidæ.

*Schizoblastus Bailii, *E. & C.*
*Schizoblastus Rofei, *E. & C.*
*Acentrotremites ellipticus, *Cumberland*, sp.

Granatoblastidæ.

*Granatocrinus campanulatus, *McCoy*, sp.
*Granatocrinus Derbiensis, *Sowerby*, sp.
*Granatocrinus ellipticus, *Sowerby*, sp.
*Granatocrinus McCoyi, *E. & C.*
*Granatocrinus orbicularis, *Sowerby*, sp.
*Heteroblastus Cumberlandi, *E. & C.*

Codasteridæ.

*Codaster trilobatus, *McCoy*.
*Codaster trilobatus, var. acutus, *McCoy*, var.
*Phænoschisma acutum, *Sowerby*, sp.
*Phænoschisma Benniei, *E. & C.*
*Orophocrinus pentangularis, *Miller*, sp.
*Orophocrinus prælongus, *Baily*.
*Orophocrinus verus[1], *Cumberland*, sp.

Astrocrinidæ.

*Astrocrinus Benniei, *Etheridge, jun.*
*Astrocrinus tetragonus, *T. & T. Austin.*
*Pentephyllum Adarense, *Haughton.*

Genus undetermined; country and horizon doubtful:—

[Pentremites] globosa, *Say*.

BELGIUM.

Pentremitidæ.

*Mesoblastus crenulatus, *Roemer*, sp.

Codasteridæ.

*Phænoschisma caryophyllatum, *de Koninck*, sp.
*Orophocrinus Orbignyanus, *de Koninck*, sp.
*Orophocrinus pentangularis[2], *Miller*, sp.
*Orophocrinus Puzos, *Münster*, sp.

[1] Identical with *Pentatrematites inflata*, G. B. Sowerby.
[2] Identical with *Pentremites Waterhousianus*, de Koninck.

GERMANY.

Genus undetermined, and horizon doubtful :—

[Pentremites] ovalis, *Goldfuss.*

NORTH AMERICA.

(SUBCARBONIFEROUS.)

1. **Kinderhook Group,** or **Marshall Group** (Winchell), including the Chouteau Limestone.

Nucleoblastidæ.

Schizoblastus ? Sampsoni, *Hambach,* sp.

Genus undetermined :—

[Granatocrinus] Roemeri, *Shumard* (fide *S. A. Miller*).

2. **Burlington Group**[1].

Pentremitidæ.

*U. Pentremites Burlingtonensis, *Meek & Worthen.*
*U. Pentremites elongatus, *Shumard.*

Troostoblastidæ.

*U. Metablastus lineatus, *Shumard,* sp.

Nucleoblastidæ.

*U. Schizoblastus melonoides, *Meek & Worthen,* sp.
L. Schizoblastus ? neglectus, *Meek & Worthen,* sp.
Schizoblastus Potteri, *Hambach,* sp.
Schizoblastus ? projectus, *Meek & Worthen,* sp.
*U. Schizoblastus Sayi, *Owen & Shumard,* sp.
*L. Cryptoblastus melo, *Owen & Shumard,* sp.
*U. Cryptoblastus pisum, *Meek & Worthen,* sp.

Granatoblastidæ.

*U. Granatocrinus Norwoodi, *Owen & Shumard,* sp.
U. Granatocrinus Norwoodi, var. fimbriatus, *Meek & Worthen,* var.

Codasteridæ.

*U. Codaster ? Whitei, *Hall.*
Phænoschisma ? Kentuckyensis, *Shumard,* sp.

[1] The two horizons of the Upper and Lower Burlington Limestone are distinguished by the letters U. and L. respectively, placed before the names of those species for which this point has been recorded.

Codasteridæ (*continued*).

*L. Orophocrinus gracilis, *Meek & Worthen*, sp.
*L. Orophocrinus stelliformis, *Owen & Shumard*, sp.
*L. Orophocrinus stelliformis, var. campanulatus, *Hambach*, var.

Genera undetermined:—

[Pentremites] decussatus, *Shumard.*
[Pentremites] Sirius, *White.*
*L. [Granatocrinus] Shumardi, *Meek & Worthen.*

Genus and horizon undetermined:—

[Granatocrinus] lotoblastus[1], *White.*

3. **Keokuk Group.**

Troostoblastidæ.

Metablastus bipyramidalis, *Hall*, sp.
*Metablastus Wortheni, *Hall*, sp.
*Tricœlocrinus Woodmani, *Meek & Worthen.*

Nucleoblastidæ.

Schizoblastus? granulosus, *Meek & Worthen*, sp.

Genus undetermined:—

[Codaster] gratiosus, *Miller.*

4. **St. Louis Group,** including the Warsaw Limestone.

Pentremitidæ.

Pentremites Bradleyi, *Meek, MS.*
*Pentremites conoideus, *Hall.*
*Pentremites conoideus, var. Koninckanus, *Hall*, var.
Pentremites subconoideus, *Meek, MS.*
*Mesoblastus glaber, *Meek & Worthen*, sp.

Troostoblastidæ.

Troostocrinus? Grosvenori[2], *Shumard*, sp.
*Metablastus Varsouviensis, *Meek & Worthen*, sp.
*Metablastus Wachsmuthi, *Gurley*, sp.

[1] This species has been found at two localities in the West, where the subdivisions of the Mississippi Valley series cannot be clearly made out, and its precise horizon is therefore more or less uncertain. It probably belongs to the Nucleoblastidæ, and we have therefore associated it with the Burlington Limestone, in which this family is abundantly represented.

[2] According to Shumard, this fossil was found in the Archimedes Limestone at Spergen Hill, Indiana. We do not know whether this is the bed that is generally known as the Oolitic or the Warsaw Limestone; but it does not appear to be the same as the "Upper Archimedes" or Kaskaskia Limestone of the Chester Group.

Troostoblastidæ (*continued*).

*Tricœlocrinus Meekianus, *E. & C.*
Tricœlocrinus obliquatus, *Meek & Worthen.*
*Tricœlocrinus obliquatus, *Roemer*, sp.
*Tricœlocrinus Woodmani, *Meek & Worthen.*

Nucleoblastidæ.

Cryptoblastus ? Kirkwoodensis, *Shumard*, sp.

Granatoblastidæ.

Heteroblastus ? cornutus, *Meek and Worthen*, sp.

Genera undetermined :—

[Pentatrematites] granulatus, *Roemer.*
[Pentremites] longicostalis, *Hall.*
[Pentremites] truncatus, *Conrad.*

5. **Chester Group,** including the "Pentremital" Limestone and the "Upper Archimedes" or "Kaskaskia" Limestone.

Pentremitidæ.

*Pentremites angularis, *Lyon.*
Pentremites basilaris, *Hambach.*
Pentremites Broadheadi, *Hambach.*
Pentremites calycinus, *Lyon.*
Pentremites cervinus, *Hall.*
Pentremites clavatus, *Hambach.*
Pentremites Chesteriensis, *Hambach.*
*Pentremites elegans, *Lyon.*
*Pentremites gemmiformis [1], *Hambach.*
*Pentremites globosus [2], (*Troost*) *Hall.*
*Pentremites Godoni, *Defrance*, sp.
*Pentremites Godoni, var. abbreviatus, *Hambach*, var.
*Pentremites Godoni, var. florealis, *Schlotheim*, var.
*Pentremites Godoni, var. major, *E. & C.*, var.
*Pentremites hemisphericus, *Hambach.*
Pentremites Missouriensis, *Swallow.*
Pentremites nodosus, *Hambach.*
*Pentremites obesus, *Lyon.*
*Pentremites pyriformis, *Say.*
*Pentremites pyriformis, var. symmetricus, *Hall*, var.
*Pentremites robustus, *Lyon.*

[1] This species appears to us to be merely a variety of *Pentremites clavatus*, Hambach.
[2] This species was subsequently called *P. Troosti* by Shumard.

Pentremitidæ (*continued*).

Pentremites spinosus, *Hambach.*
*Pentremites sulcatus[1], *Roemer.*

Genera undetermined:—

[Pentremites] curtus, *Shumard.*
[Pentremites] laterniformis, *Owen & Shumard.*
[Pentremites] ovalis[2], *Owen.*

Genus and horizon uncertain:—

[Pentremites] Tennesseæ, (*Troost, MS.,*) *Shumard.*

[1] Probably identical with *P. Cherokeeus*, Hall, and also, according to Hambach, with the internal cast described as *P. laterniformis* by Owen and Shumard. We do not think, however, that this is the case.
[2] We have not been able to consult the work in which this species is recorded.

CHAPTER VIII.

DESCRIPTIONS OF THE SPECIES.

The diagnoses of the numerous species of Blastoidea which are represented in the National Collection may be conveniently preceded by the following table of the orders, families, and genera.

Class BLASTOIDEA.

Order REGULARES, *E. & C.*, 1886.

Pedunculate Blastoids with a symmetrical base, in which the radials and ambulacra are all equal and similar.

1st Family. *PENTREMITIDÆ*, d'Orbigny, 1852 (emend. E. & C., 1886).

Base usually convex and often much elongated. Spiracles five, but sometimes more or less completely divided by a median septum. Their distal boundary formed by side plates. Hydrospires concentrated at the lowest part of the radial sinus.

Pentremites, Say. *Pentremitidea*, d'Orb. *Mesoblastus*, E. & C.

2nd Family. *TROOSTOBLASTIDÆ*, E. & C., 1886.

Ambulacra very narrow and descending sharply outwards from the much restricted peristome. Deltoids usually limited to the summit and rarely visible externally. Lancet-plate entirely covered by the side plates. Spiracles generally double, appearing as linear slits at the sides of the deltoid ridge, but not bounded distally by side plates.

Troostocrinus, Shumard. *Metablastus*, E. & C.
Tricœlocrinus, Meek and Worthen.

3rd Family. *NUCLEOBLASTIDÆ*, E. & C., 1886.

Calyx usually globular or ovoidal, with flattened or concave base and linear ambulacra. Spiracles distinctly double, and chiefly formed by the apposition of notches in the lancet-plate and deltoids.

(i.) Subfamily Elæacrinidæ, *E. & C.*, 1886.

Posterior deltoid divided into two parts by an anal plate. Anus distinct from posterior spiracles.

Elæacrinus, Roemer.

(ii.) Subfamily SCHIZOBLASTIDÆ, *E. & C.*, 1886.

No anal plate. Posterior spiracles may be fused with anus.

Schizoblastus, E. & C. *Cryptoblastus*, E. & C.
Acentrotremites, E. & C.

4th Family. *GRANATOBLASTIDÆ*, E. & C., 1886.

Calyx globular or ovoidal, with flattened or concave base and linear ambulacra. Spiracles five, piercing the deltoids; or ten, grooving their lateral edges.

Granatocrinus, Troost. *Heteroblastus*, E. & C., 1886.

5th Family. *CODASTERIDÆ*, E. & C., 1886.

Base usually well developed and sometimes very long. Some, or all of the hydrospire-slits pierce the calyx-plates on the sides of the radial sinus, restricted portions of which may remain open as the spiracles.

(i.) Subfamily PHÆNOSCHISMIDÆ, *E. & C.*, 1886.

Eight or ten groups of hydrospire-slits, which are partially or entirely visible. Deltoids limited to the summit, not appearing externally.

Codaster, McCoy. *Phænoschisma*, E. & C.

(ii.) Subfamily CRYPTOSCHISMIDÆ, *E. & C.*, 1886.

Ten groups of hydrospire-slits, few or none of which appear at the sides of the ambulacra. Deltoids small and external, or limited to the summit.

Orophocrinus, von Seebach. *Cryptoschisma*, E. & C.

Order IRREGULARES, *E. & C.*, 1886.

Unstalked Blastoids, in which one ambulacrum and the corresponding radial are different from their fellows. Base usually unsymmetrical.

6th Family. *ASTROCRINIDÆ*, T. & T. Austin, 1842 (emend. E. & C., 1886).

(i) Basals unsymmetrical. Azygos radial small and without definite limbs; its ambulacrum short, wide, and horizontal.

Astrocrinus, T. & T. Austin. *Eleutherocrinus*, Shumard & Yandell.

(ii) Basals symmetrical; odd ambulacrum linear.

Pentephyllum, Haughton.

Let us now proceed to consider this classification in more detail, and to study the mutual relations of the genera which constitute the six families defined above.

Order REGULARES, *E. & C.*, 1886.

Definition. Pedunculate Blastoids with a symmetrical base, in which the radials and ambulacra are all equal and similar.

Remarks. Little need be said about this group, which comprises all the types of Blastoidea that were recognized by Roemer in 1851 as belonging to this class. He was acquainted with Austin's *Astrocrinus*, but was inclined to exclude it from the Blastoidea on account of its apparently tetramerous symmetry [1]; while the allied genus *Eleutherocrinus* had not then been discovered.

Neither of these two genera, nor *Pentephyllum*, has any indication of the presence of a stem; while this is not known to have been wanting in any of the regular Blastoids, in which also the five radials and the ambulacra corresponding to them are perfectly homogeneous in character. All the interambulacral angles at the peristome are of equal size, and no radial nor ambulacrum is different from its fellows. This is so evident upon a glance at any of our first sixteen Plates, that nothing more need be said upon the subject.

The regular Blastoids fall very naturally into five families, three of which are typified by genera recognized by Roemer, viz. *Pentremites, Elæacrinus*, and *Codaster*. The leading forms of the other two families, *Granatoblastidæ* and *Troostoblastidæ*, are the species which he regarded as the types of his *Pentremites Elliptici* and *Pentremites Clavati* respectively. It will be evident, therefore, that our classification has followed very closely upon the lines which he had laid down when the science of Blastoid morphology was as yet in its infancy. We believe, however, that there are some new features in it; but we are quite prepared to hear Mr. Hambach's valuable criticism [2] again repeated:—"The mere recapitulation of what has been done by others is of very little value, even if a different terminology is used for it."

Family *PENTREMITIDÆ*, d'Orbigny, 1852 (emend., E. & C., 1886).

Definition. Base usually convex and often much elongated. Spiracles five, but sometimes more or less completely divided by a median septum. Their distal boundary formed by side plates. Hydrospires concentrated at the lowest part of the radial sinus.

[1] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 390.

[2] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, p. 547.

Remarks. This family was established by d'Orbigny[1] in 1852 as one of the twelve into which he divided the Crinoidea, and it is practically coextensive with the "family" Blastoidea of Say. According to d'Orbigny, it included armless Crinoids which have the "calice ovalaire, solide, pourvu de cinq ambulacres réunis supérieurement; chacun strié en travers, pourvu d'un sillon au milieu et d'un pore à son sommet."

This definition would apply equally well to almost every one of the regular Blastoids, except as regards the pore at the summit of each ambulacrum. The extended form of it which was given by Dujardin and Hupé[2] commences with the remarkable statement that "les Blastoïdes, ou Pentrémitides, sont dépourvus d'appareil digestif." For they believed the mouth to be only an "hiatus," and regarded the anus as an ovarian opening. The remainder of their definition, which is too long to quote, was based essentially upon Roemer's monograph, and, like him, they only included in the "family" the three genera *Pentremites*, *Elæacrinus*, and *Codaster*.

S. A. Miller has limited the family Pentremitidæ, though without defining it in any way, to the genera *Pentremites* and *Granatocrinus*. But we have been obliged to remove the latter genus into a family of its own, as the presence of an hydrospire-plate and the actual perforation of the deltoids by the spiracles distinguish it very sharply both from *Pentremites* and from *Pentremitidea*.

The leading character of this family, as restricted by us, is the fact that the lancet-plate does not fill the radial sinus, but leaves a passage on each side, which is bridged over by the side plates. These form a roof to the hydrospire-canal, and also enter into the distal border of the spiracle, as seen in *Pentremites* (Pl. I. fig. 6; Pl. XVI. fig. 21), *Pentremitidea* (Pl. IV. fig. 14; Pl. V. figs. 3, 19), and in *Mesoblastus* (Pl. VI. figs. 8, 13).

There is nothing of this kind in *Orophocrinus*, although the side plates may project beyond the edge of the lancet-plate (Pl. XI. fig. 8); while the hydrospires of *Cryptoschisma* (Pl. V. fig. 24), or of *Phænoschisma Archiaci* and *P. caryophyllatum* (Pl. XIV. figs. 2–7) are altogether different from those of the Pentremitidæ, although the side plates project beyond the lancet-plate as in this family.

Of the three genera which we refer to it, *Pentremitidea* occupies a curiously intermediate position. For it has narrow ambulacra like *Mesoblastus*, but lacks the hydrospire-plate of this genus, and in this respect it resembles *Pentremites*. In the typical forms of the latter genus, and also in those of *Pentremitidea*, no division of the five spiracular openings can be made out (Pl. I. figs. 4, 10; Pl. V. figs. 2, 4), though it is sometimes rather marked (Pl. I. figs. 5, 6, 11; Pl. IV. fig. 14); while it is

[1] 'Cours élémentaire de Paléontologie et de Géologie stratigraphique,' Paris, 1852, t. ii. fasc. 1, p. 139.

[2] 'Hist. Nat. des Zoophytes Échinodermes,' 1862, pp. 56, 85.

always more or less traceable in *Mesoblastus* (Pl. IV. fig. 1; Pl. VI. fig. 13), sometimes indeed rather prominently so (Pl. VI. figs. 7, 8). But in all cases alike the hydrospire-canal is bridged over by side plates, whether they rest against the lancet-plate as in *Pentremites*, or partially cover it as in *Mesoblastus* and *Pentremitidea*.

The latter genus passes very gradually into *Pentremites*, especially as regards the external appearance of the deltoids. They are very small in *Pentremites angularis* and *P. calycinus*, and also in some forms of *P. pyriformis* (Pl. II. figs. 29, 30), from which last it is but a step to certain species of *Pentremitidea* (Pl. V. figs. 6, 7, 16); while in *Pentremitidea*? *leda*, Hall, sp. (Pl. V. figs. 12, 13), they are as large as in many true *Pentremites* (Pl. II. figs. 19–23), though the linear shape of the ambulacra and the relation of the side plates to the lancet-plate seem to fix the generic position of this species without any difficulty.

The mutual relations of the three genera of the Pentremitidæ are shown in the following scheme:—

A. Ambulacra usually broad and petaloid; the lancet-plate not covered by side plates, which only rest against its edge.	*Pentremites*, Say.
B. Ambulacra usually narrow and linear; the lancet-plate more or less concealed by the side plates which rest upon it.	
(1) Base generally elongated. Deltoids usually invisible upon the exterior of the calyx. No hydrospire-plate.	*Pentremitidea*, d'Orbigny.
(2) Base inconspicuous and somewhat flattened. Deltoids appear externally. An hydrospire-plate.	*Mesoblastus*, E. & C.

In the following descriptions we use the word "periphery" to denote the level at which the horizontal diameter of the calyx is greatest; while "summit" denotes that portion of the surface of the calyx which is included between the proximal ends of those parts of the deltoid plates which appear externally above the radial limbs, or between the ends of these limbs themselves when the deltoids do not appear externally.

Genus PENTREMITES, *Say*, 1820 (*emend. E. & C.*, 1886).

Pentremites, Say, American Journ. Sci. 1820, vol. ii. p. 36.

Pentremites, Say, Journ. Acad. Nat. Sci. Philad. 1825, vol. iv. pt. 2, p. 292.

Mitra (pars), Cumberland, Reliquiæ Conservatæ, 1826, p. 31.
Pentremites (pars), McCoy, Synop. Carb. Limest. Foss. Ireland, 1844, p. 174.
Pentremites, Goldfuss, Petrefacta Germaniæ, 1826, Theil i. p. 160.
Pentatrematites Floreales (pars), Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 353.
Pentremites, Lyon, Owen's 3rd Kentucky Geol. Report, 1857, p. 468.
Pentremites (pars), Pictet, Traité de Pal. 1857, tome iv. p. 292.
Pentremites (pars), Hall, Iowa Geol. Survey Report, 1858, vol. i. pt. 2, p. 89.
Pentremites, Lyon, Trans. St. Louis Acad. Sci. 1860, vol. i. no. 4, p. 628.
Pentremites (pars), Dujardin & Hupé, Hist. Nat. Zooph. Échinod. 1862, p. 89.
Pentremites (pars), Billings, American Journ. Sci. 1869, vol. xlviii. p. 80, 1870, vol. l. p. 226.
Pentremites (pars), Miller, Cat. American Pal. Foss. 1877, p. 85.
Pentremites (pars), Zittel, Handb. Pal. 1879, Bd. i. Lief. 3, p. 434.
Pentremites, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 219.

Gen. Char. Calyx variable in size and form, but usually ovate or pyriform, or some combination of the two; summit broad, or more or less contracted, sometimes truncated and flat, seldom convex; base occasionally subtruncate, but more frequently elongate and cuplike, never distinctly trilobate, nor excavated in the middle line; section always more or less pentagonal, and either with straight sides, or the latter occupied by slight re-entering angles; periphery variable, sometimes at the radial lips, but more frequently equatorial, or nearly so. Basal plates small, forming a small cup, which varies in outline from shallow basin-shaped to depressed funnel-shaped, but these plates never form more than a third of the calyx, and seldom even so much. Radial plates long, usually forming by far the greater portion of the calyx, and of variable convexity; bodies usually small, seldom equalling the limbs in length, and often subcarinate in the middle line; limbs long, with flat or concave sides, and always obliquely truncated above; sinuses broad and subpetaloid, of variable length, and frequently with sharp erect margins; lips simple, or sometimes thickened and projecting. Deltoid plates always small, irregularly rhombic, or lanceolate, sometimes concave in the middle line, never horizontal, or produced above into tube-like extensions. Ambulacra broad, subpetaloid, either flat or convex, and sometimes rather deeply sunken in the sinuses; lancet-plates elongate, somewhat triangular in section, resting below on under lancet-plates, and usually forming about a third of the entire width of the ambulacra, but not wholly filling the sinuses, and flat or slightly convex on their exposed surfaces. Side plates and outer side plates numerous, of variable form, and more or less developed according to species, the former abutting against the edges of the lancet-plates. The hydrospire-pores partially excavated out of the sides of the sinuses; pinnules attached between the pores, and formed of a single or partially double row of small plates; hydrospires variable in number, from three to nine, pendent, but partially contained within the substance of the radial plates near their distal ends. Spiracles single, but occasionally double, usually more or less

pyriform in shape, partially excavated in the substance of the deltoid plates, and otherwise bounded by the lancet-plate and proximal side plates. Posterior spiracles confluent with the anus, the combined aperture being somewhat larger than the other spiracles. Peristome of variable size, covered by a small dome of minute polygonal plates, which may also cover the spiracles[1], and is continued outwards as alternating covering plates above the ambulacral grooves. Column round, and composed of thin discoidal joints. Ornament consisting of fine striæ arranged parallel to the margins of the plates.

History. If we omit for the present the genera *Eleutherocrinus*, Lyon & Casseday, *Astrocrinus*, T. & T. Austin, and *Pentephyllum*, Haughton, the history of the genus *Pentremites*, as formerly understood, is practically that of nearly all the genera which we shall subsequently describe. We shall, however, confine our historical remarks to that group of species for which we restricted the name in 1882.

The genus was originally proposed by Say in 1820, when, in addition to the general characters of the calyx, he described the structure of the ambulacra, and said that each of the apertures which we now call the spiracles "is the common aperture of two tubes." He further supposed that "tentacula" (*i. e.* tube-feet) were protruded "through the pores of the Ambulacræ," as is the case in the Echinoidea.

In 1835 Dr. G. Troost[2] described the component parts of the ambulacra and the construction of the ambulacral or hydrospire-pores in various species of *Pentremites*; and he noticed that each of the spiracular openings is often "divided into two parts by a septum."

The existence of the ambulacral appendages or "pinnulæ" was noticed independently by Dr. F. Roemer and Prof. L. P. Yandell, in 1848[3], in specimens of *Pentremites pyriformis* and *P. Godoni*. Messrs. Owen and Shumard[4] have also described the pinnules of *P. Godoni*, and a conical integument of small plates closing the five summit apertures or spiracles. Mr. S. S. Lyon published some interesting remarks in 1857, in which he endeavoured to prove the existence of "supplementary" basal plates in the Pentremite calyx, underlying those usually called basals. This view has been adopted by some Palæontologists, and rejected by others, including ourselves (see pp. 18–22).

Dr. F. B. Shumard published some additional important observations on the summit structure of *Pentremites* in 1858[5], in which he showed that the mouth and spiracles of *P. conoideus*, Hall, and *P. sulcatus*, Roemer, were covered in the one case by six small pentagonal plates over each opening, whilst in the latter the

[1] Or each aperture may be separately closed by six small pentagonal plates according to Shumard.
[2] Trans. Geol. Soc. Pennsylv. 1835, vol. i. p. 227.
[3] Bull. Soc. Géol. France, 1848, tome v. p. 296.
[4] Report Geol. Survey, Wisconsin, Iowa, and Minnesota, 1852, p. 592.
[5] Trans. St. Louis Acad. Sci. 1858, vol. i. no. 2, p. 243.

apertures were covered by a single dome-shaped integument composed of very small plates apparently like that previously described in *P. Godoni.* Additional observations on the structure and position of the pinnules were made in 1862 by Prof. James Hall, who appears to have had excellent material for this purpose in *Pentremites Whitei*[1], and also by Dr. C. A. White[2], who discovered them in *P. elongatus*, Shumard. He describes the pinnules as apparently connected directly with the outer side plates, and adds, "They are directed obliquely toward the centre of the pseudambulacral field, for a short distance, and are then bent directly upward, and lie side by side, nearly filling the field. . . . They appear to be composed of a double series of short, angular plates, with parallel sutures, so arranged that the sutures between the plates of one series are opposite the middle of the plates of the other series."

The most important researches on the Blastoids made in Great Britain for many years were those published in 1865 by the late Mr. John Rofe[3], but they will more properly be noticed in the history of *Granatocrinus.* His remarks have reference to the hydrospires and lancet-plate which he was the first to display by the section method in *P. Godoni*, and indeed in any Blastoid.

In 1869 the late Mr. Billings described the presence of a small pore at the proximal end of each (partially covered) ambulacral groove in *Pentremites conoideus*[4], and he regarded them as ovarian in function. He further supported Lyon's description of the so-called "supplemental basals," and also Rofe's view of the respiratory character of the hydrospires as he proposed to call them. We are likewise indebted to this careful observer for a minute study of the ambulacra of *Pentremites pyriformis*, which with the earlier and corresponding observations made by Troost on *P. Godoni* may be said to have pretty definitely fixed the structure of this part of the Pentremite economy.

Messrs. Meek and Worthen[5] have shown that in *Pentremites Burlingtonensis* the spiracles, usually single in this genus, are double, and appear "at the surface as four pairs of elongate oval pores." They thus depart considerably from the usual structure of the spiracles in *Pentremites* and approach those of *Mesoblastus.* The hydrospires of *Pentremites* have formed the subject of close study by Messrs. Wachsmuth and Springer[6], who have described these organs in detail, and, like Billings, believe them to have served the same functions as the pectinated rhombs of the Cystidea. They have further detected an important addition to the lancet-plate, in the form of an under lancet-plate, which they describe as perforated by a tubular passage[7], and they likewise discovered the ambulacral opening between the deltoids (Pl. I. figs. 6, 7).

[1] Fifteenth Ann. Rep. New York State Cab. Nat. Hist. 1862, p. 150.

[2] Boston Journ. Nat. Hist. 1862, vol. vii. no. 3, p. 488.

[3] Geol. Mag. 1865, vol. ii. p. 249.

[4] American Journ. Sci. 1869, vol. xlvii. p. 353, *ibid.* 1869, vol. xlviii. p. 81, f. 15. M'Coy had previously suggested the presence of "ocular pores" in this position when describing other species which now fall into *Granatocrinus* (Brit. Pal. Foss. 1851, fas. 1, p. 123).

[5] Report Geol. Survey Illinois, 1873, vol. v. p. 462.

[6] Revision of the Palæocrinoidea, Part I. 1879, p. 7.

[7] *Ibid.* t. xvii. f. 5.

The last reference we have to make in the structural history of *Pentremites* is the discovery by Mr. G. Hambach[1] of a fine canal piercing the lancet-plate itself, apparently in addition to that just mentioned. This canal was subsequently observed by ourselves[2], and we described it as passing inwards through the ambulacral opening discovered by Wachsmuth and Springer to join an oral ring which we regarded as belonging to the water-vascular system. Hambach has since seen this ring, but has altogether misunderstood its relations, as we have explained on pp. 51–54.

Remarks. The foregoing generic description has been drawn up with the view of limiting the name *Pentremites* to those Blastoids which resemble *P. Godoni*, Defrance, *P. sulcatus*, Roemer, and *P. pyriformis*, Say, in their structure and general appearance. The general form is ovoid or pyriform, and the ambulacra are broad and petaloid. In most (if not in all) species the side plates merely rest against the edges of the lancet-plates, without covering any part of them.

Another and an equally important distinguishing feature of *Pentremites* is the structure of the spiracles. The central end of each deltoid plate is flat and laterally expanded, with a more or less marked oral ridge in the middle line that divides it into two lateral halves. Each half forms the floor of a passage leading along the lower part of the radial sinus over the upper ends of the hydrospire-slits. This is converted into a canal by the side plates, which are wedged in between the lancet-plate and the side of the radial sinus. Those nearest the centre may either meet one another over the oral ridge (Pl. I. fig. 4) or abut against its sides (Pl. I. figs. 5, 10, 11), thus enclosing the opening of the spiracle. In all those *Pentremites* in which we have been able to examine the internal organs, the hydrospire-tubes beneath the ambulacra extend along the entire length of the radial sinuses and communicate with the exterior by the marginal pores and the spiracles; but a peculiar modification occurs in some species, the distal portion of the hydrospires being received into the substance of the radial plates (Pl. II. fig. 31), as we have described on p. 95.

Some valuable observations have been recently made by Messrs. Wachsmuth and Springer, and by Mr. Hambach, on the structure of the ambulacra in Blastoids, more especially as regards the lancet-plates. The former authors have described and figured the lancet-plate of *Pentremites* as imperforate, but as resting on an under lancet-plate which encloses a canal. Hambach, on the other hand, describes the lancet-plate of typical *Pentremites* (*P. florealis*, *P. sulcatus*, *P. pyriformis*, &c.) as "pierced through the centre, in its whole length, by a very fine canal," and we are inclined to think that he is right (Pl. XVIII. figs. 3, 4, 6). For, although we agree with Wachsmuth and Springer in finding two subambulacral pieces in *Pentremites*,

[1] Trans. St. Louis Acad. Sci. 1880, vol. iv. no. 1, p. 149.

[2] Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 218.

it seems to us more probable that the canal should be in the upper or lancet-piece, as in *Granatocrinus* and *Mesoblastus* (Pl. XVII. figs. 4–10), than in the lower and much thinner under lancet-piece which is unrepresented in most other Blastoids [1].

Our actual knowledge of the genus *Pentremites* has been gained from a limited, though typical and well-defined, series of species. We are unable therefore to give so complete a general epitome of the calyx structure in this genus as we could wish, and similar to what we have tried to give for other genera. Confining our remarks therefore to those species which we have personally examined we may state generally that—The summit of the calyx in *Pentremites* is usually broad (Pl. II. figs. 1–7, 24–30), but that in *P. elongatus* it is less so (Pl. II. figs. 14, 15), and narrower still in *P. conoideus* (Pl. II. figs. 16–18; Pl. III. fig. 4). The base may be very short and almost truncate as in *P. conoideus* and *P. elongatus*, rather more elongate in *P. Godoni* and its varieties, and still more so in *P. pyriformis* (Pl. II. figs. 24–30), but so far as we know it is never absolutely concave. The form of the basal cup varies in proportion to the length of the base. It is almost flat and saucer-shaped in *P. conoideus* (Pl. II. fig. 16; Pl. III. fig. 4), deeper and larger in some forms of *P. Godoni*, more elongate in *P. sulcatus*, *P. obesus*, and *P. Chesteriensis*, and most so in *P. pyriformis* with its variety *symmetricus*, and in *P. clavatus*.

The radial plates differ but little, except in the amount of vertical and transverse convexity, which last reaches its greatest limit in the extreme forms of *P. sulcatus*. They are relatively longest in *P. elongatus* and *P. conoideus* (Pl. II. figs. 14–17), and perhaps shortest in *P. symmetricus* (Pl. II. fig. 24). The sinuses are always wide and subpetaloid, whilst in certain species, such as *P. sulcatus*, and in some forms of *P. Godoni*, the edges are remarkably sharp and erect.

The deltoid plates are usually small, and more or less rhombic, although in *P. elongatus* they become lanceolate, owing to the lengthening of the calyx; their surfaces as a rule are concave, especially at the outer ends of the plates.

The ambulacra do not vary greatly in the more general points of detail. They may be either flat, or nearly so, as in *P. pyriformis*, their respective halves convex, as in *P. Godoni*, or inclined inwards towards one another, producing a highly concave ambulacrum, as in *P. sulcatus*.

We are acquainted with the hydrospires of *P. Godoni*, in which there are from three to five folds on each side (Pl. XVI. fig. 19); *P. elongatus* possesses three (Pl. XVIII. fig. 4), *P. conoideus* four (fig. 6), *P. sulcatus* four or five (Pl. XVI. fig. 20), and *P. pyriformis* from five to seven (Pl. XVIII. fig. 3). The spiracles are single in the great majority of the species, but in *P. Burlingtonensis* they are double, and in *P. elongatus* sometimes double, sometimes single (Pl. I. figs. 4, 5).

The enclosure of the distal portions of the hydrospires of *Pentremites* within the radial plates has been already described on p. 95. It causes the ambulacrum

[1] This subject is fully discussed on pp. 50–54.

to appear shorter on the internal cast than on the exterior of the calyx, as is well shown on Pl. III. fig. 4. Hambach[1] figures a specimen of *P. sulcatus* which illustrates this point very well; but we think that he is wrong in identifying this internal cast of *P. sulcatus* with that which was described as *P. laterniformis* by Owen and Shumard[2]. The latter is a much higher cast than the one figured by Hambach, who does not appear to be aware that the appearance presented by *P. laterniformis* may be repeated in casts of other species besides *P. sulcatus*.

Species. For us to give a full and at the same time anything like an accurate list of the species of *Pentremites* would be an impossibility. We are convinced that many synonyms exist, but as the genus is so essentially an American one and is limited to the Subcarboniferous, we must leave to some Palæontologist of that country the task of unravelling this perplexing subject. At present we intend to indicate only those species with which we believe ourselves to be personally acquainted.

Pentremites angularis, Lyon. Chester Group; Illinois and Kentucky.
Pentremites Burlingtonensis, M. & W. Burlington Limestone; Iowa.
Pentremites conoideus, Hall. Warsaw Limestone; Indiana.
Pentremites conoideus, var. *Koninckanus*, Hall. Warsaw Limestone; Indiana.
Pentremites elegans, Lyon. Kaskaskia Limestone; Illinois.
Pentremites elongatus, Shumard. Burlington Limestone; Iowa.
Pentremites gemmiformis, Hambach. Kaskaskia Limestone; Illinois.
Pentremites globosus (Troost), Hall. Kaskaskia Limestone; Illinois.
Pentremites Godoni, Defrance. Kaskaskia Limestone; Alabama, &c.
Pentremites Godoni, var. *abbreviatus*, Hambach. Kaskaskia Limestone; Illinois.
Pentremites Godoni, var. *florealis*, von Schlotheim. Kaskaskia Limestone; Alabama.
Pentremites Godoni, var. *major*, E. & C. Kaskaskia Limestone; Tennessee.
Pentremites hemisphericus, Hambach. Kaskaskia Limestone; Illinois.
Pentremites obesus, Lyon. Kaskaskia Limestone; Kentucky.
Pentremites pyriformis, Say. Kaskaskia Limestone; Alabama, &c.
Pentremites pyriformis, var. *symmetricus*, Hall. *Ibid.*; Kentucky.
Pentremites robustus, Lyon. Chester Group; Illinois and Kentucky.
Pentremites sulcatus, Roemer. Kaskaskia Limestone; Illinois.

Distribution. The genus *Pentremites*, as restricted by us, is essentially Carboniferous and strictly American, with one possible exception. We refer to *P. ovalis*, Goldfuss[3], a form with which we are unfortunately not acquainted. It was said to come from the Transition Limestone (Devonian) of Cromford, near Ratingen, Düsseldorf; and our friend Professor F. Roemer informs us, that though obtained from a large quarry of Carboniferous Limestone it was found " not in the thick bedded Carboniferous Lime-

[1] Trans. St. Louis Acad. Sci. 1880, vol. iv. no. 1, p. 147, pl. B. fig. 10.
[2] Wisconsin, Iowa, and Minnesota Geol. Report, 1852, p. 592, tab. V *a*. fig. 15.
[3] Petrefacta Germaniæ, 1826, Theil i. p. 161.

stone itself, but in slatish beds which are possibly of Devonian age." We have been unable to examine the specimen, and do not know if it be a true *Pentremites* or not. If so it is strange that only one European species should be known, for Goldfuss's figure appears to represent a true *Pentremites,* although on closer examination the specimen might be found to differ from this type. Its geological and its systematic position are therefore alike uncertain. Apart from this doubtful type the earliest known species of *Pentremites* are the *P. elongatus* and *P. Burlingtonensis* of the Upper Burlington Limestone. We know of no species from the Keokuk group; while the only representatives of the genus in the Warsaw Limestone are *P. conoideus* and its variety *Koninckanus.* The Chester Limestone, however, is fairly crammed with several species of *Pentremites.*

Type. Encrina Godoni, Defrance.

PENTREMITES GODONI, *Defrance*, sp.

(Pl. I. fig. 11; Pl. II. figs. 1–13; Pl. XII. figs. 16, 17; Pl. XVI. figs. 19, 22, 23.)

Asterial Fossil, Parkinson, Organic Remains, 1808, vol. ii. p. 235, t. 13. f. 36 & 37.
Asterite from Kentucky, Mitchell, in Cuvier's Theory of the Earth, N. York edit. 1818, t. 8. f. 6.
Encrina Godoni, Defrance, Dict. Sci. Nat. 1819, tome xiv. p. 467.
Encrinites florealis, von Schlotheim, Petrefactenkunde, 1820, Bd. ii. p. 38.
Pentremite (*Kentucky Asterial Fossil*), Say, American Journ. Sci. 1820, vol. ii. p. 38.
Pentremites florealis, Say, Journ. Acad. Nat. Sci. Philad. 1825, vol. iv. pt. 2, p. 295; Zool. Journ. 1825, vol. ii. no. 7, p. 314.
Pentremites florealis, G. B. Sowerby, Zool. Journ. 1825, vol. ii. no. 7, t. 11. f. 2 (3 figs.).
Mitra rugoso, quinque perforata, Cumberland, Reliquiæ Conservatæ, 1826, p. 34, t. A (non B), f. 1–3.
Pentremites florealis, Goldfuss, Petrefacta Germaniæ, 1826, Theil i. p. 161, t. 50. f. 2, *a–c*.
Pentremites florealis, Troost, Trans. Geol. Soc. Pennsyl. 1835, vol. i. pt. 2, p. 224, t. 10. f. 10 & 11.
Pentatrematites florealis, Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 353, t. 4. f. 1–4, t. 5. f. 8.
Pentatrematites florealis, Roemer, in Bronn's Lethæa Geogn. Dritte Aufl. 1852–54, Theil ii. p. 281, t. 4'. f. 8, *a–d*.
Pentremites florealis, O. & S., Wisconsin, Iowa, and Minnesota Geol. Report, 1852, p. 592.
Pentremites Godoni, Hall, Iowa Geol. Report, 1858, vol. ii. pt. 2, p. 692, t. 25. f. 13, *a* & *b*.
Pentremites Godoni, Shumard, Trans. St. Louis Acad. Sci. 1858, vol. i. no. 2, p. 245.
Pentremites Godoni, et *florealis,* Lyon & Casseday, Proc. American Acad. 1860, vol. iv. p. 296.
Pentatremites florealis, Bronn, Klassen und Ordn. Thier-Reichs, 1860, Bd. ii. t. 23. f. 1, A–E.
Pentremites florealis, Dujardin & Hupé, Hist. Nat. Zooph. Échinod. 1862, p. 90.
Pentremites Godoni, Shumard, Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 384.
Pentremites Godoni, Billings, American Journ. Sci. 1869, vol. xlviii. p. 81. fig. 13.
Pentremites florealis, Quenstedt, Petrefactenk. Deutschlands, 1876, Bd. iv. p. 714, Atlas, t. 114. figs. 65–67.
Pentremites Godoni, White, in Collett's 2nd Ann. Report, Dept. Stat. and Geol. Indiana, 1880, p. 511, t. 7. f. 10 and 11.

Sp. Char. Calyx short, or moderately long, ovoid, round-ovoid, ovoid-oblong, or ovoid-conoidal; summit more or less truncate; peristome usually concave; base subtruncate or flattened, but never absolutely cut off at right angles to the vertical axis; section obtusely pentangular; periphery sometimes at the radial lips, but more commonly above them. Basal plates forming a shallow, saucer-like slightly protuberant cup, always more or less visible in a side view, and presenting in the middle line a small papillary elevation, on which is placed the columnar facet. Radials pentagonal oblong in outline, occupying about half the length of the calyx; bodies more or less abruptly deflected inwards and downwards, and obliquely subangular in the middle line; limbs narrow, with rather steep sides; sinuses broad and deep, with sharp prominent margins; lips quite simple; interradial sutures in concavities. Deltoid-plates rhombic-lanceolate, sharp edged, and concave, their external apices not reaching the summit. Ambulacra more or less concave; lancet-plates take up about half their entire width; ambulacral groove wide, shallow, and straight, the lateral grooves almost at right angles to the main groove; side plates oblong, thirty to forty; outer side plates very small; pores elongately pyriform. Hydrospire-folds four or five (? sometimes three) on each side of an ambulacrum, and always closely approximated beneath it. Spiracles triangular-ovate, the septa short and confined to the outer ends of the openings; the anal spiracle usually with a more elevated outer edge than the others. Mouth moderately large. Ornament seldom preserved.

Remarks. Pentremites Godoni, or as it has been more frequently, though incorrectly, called *P. florealis*, appears to have been universally accepted as the type, not only of the genus *Pentremites*, but also of the entire group Blastoidea. According to the ordinary rules of nomenclature, *P. globosa*, Say, should be considered as such because it was the first species described by Say. So much difference of opinion, however, appears to exist as to what is *P. globosa*, Say, that we think it would much simplify matters were this name totally expunged [1]. The species next described, *P. pyriformis*, Say, should take its place, and although this would be the correct course to pursue, we hesitate to displace *P. Godoni* from a position so long occupied by it with advantage.

Either Shumard or Hall appears to have been the first to refer to this species in 1858 under its true name, *P. Godoni*, Defr., sp. In fact with the exception of Messrs. Lyon and Casseday, they were the only authors who used this name, until a comparatively recent period. *P. Godoni* is very abundant, and is to be met with in all collections. Say says, "Near Huntsville they are very numerous, and on the surface of a fragment of rock, three inches long by two and a quarter wide, . . .

[1] If the specimen which Say described by this name really came from the neighbourhood of Bath, it is not improbably our *Acentrotremites ellipticus* (Pl. XIII. figs. 17, 18), which occurs in the Carboniferous Limestone of Somersetshire.

I have enumerated eighteen specimens of this species . . . . On another still smaller piece of rock are twenty-one specimens . . . On a third fragment of rock thirty may be counted, and on a fourth upwards of fifty"[1].

In the ambulacra of *P. Godoni* the lateral grooves are not quite at right angles to the main groove, but are inclined very slightly downwards. The outer ends of these depressions can hardly be called sockets, like those described by the late Mr. Billings in *P. pyriformis*, but each of them is simply a fine tailing off of the groove. Both the pores and the sockets at the ends of the short grooves proceeding from them appear to be more or less of a pyriform shape. Billings described five hydrospire folds on each side of an ambulacrum in *P. Godoni*, whilst Roemer figured four, five, and six respectively. We have seen four and five, but four appears to be the more common number (Pl. II. fig. 13; Pl. XVI. fig. 19).

We have been much perplexed as to the limits of this species, but we have examined a very large number of specimens and the result has been that six, or perhaps seven, varieties have been distinguished. We have endeavoured to illustrate these gradations by a series of outline drawings of the natural size (Pl. II. figs. 1–7). They are:—

1. Large elongated variety approaching *P. Burlingtonensis*, M. & W., in its general outline (?=*Mitra rugoso, quinque perforata*, Cumberland). (Pl. II. fig. 1.)

2. Ordinary ovoid form, with the bodies of the radials more or less at right angles to the vertical axis. This may be termed the species proper. (Pl. II. fig. 3.)

3. Calyx sharper and longer than the preceding, with the bodies of the radials much more inclined to the vertical axis. (Pl. II. fig. 2.)

4. Calyx shorter and more expanded, subtruncate below, (=*P. abbreviatus*, Hambach). (Pl. II. fig. 4.)

5. Calyx similar, but with the bodies of the radials very oblique to the longer axis. (Pl. II. fig. 6.)

6. Calyx squat and expanded, almost truncate below, and the ambulacra much bent down. (Pl. II. fig. 5.)

7. Calyx small and almost globular, with wide and deeply petaloid ambulacra. (Pl. II. fig. 7.)

By the kindness of Mr. Wachsmuth we are also enabled to figure an extremely young condition of this species which is about the size of a small pea (Pl. XVI. figs. 22, 23). Its characters are sufficiently evident from our figures, which render further remarks unnecessary.

We are also indebted to him for the opportunity of examining the various malformations of the calyx which are figured on Pl. II. figs. 8–12, and described on pp. 40, 41.

It does not appear to have been generally noticed that Troost[2], in describing *P. Godoni*, considered *Pentremites ellipticus*, G. B. Sby., as a synonym of it!

[1] Journ. Acad. Nat. Sci. Philad. 1825, vol. iv. pt. 2, p. 295.

[2] Trans. Geol. Soc. Pennsylv. 1835, vol. i. pt. 2, p. 229.

Localities and Horizon. Franklin County, Tennessee (Presented by Prof. T. R. Jones, F.R.S.); Huntsville, Alabama; Chester, Illinois: Kaskaskia Limestone, Chester Group, Subcarboniferous. Floyd County, Georgia, (Presented by the late J. Rofe, Esq., F.G.S.); Leipzig, Pope County, Illinois; Alleghanie Mountains, (Presented by J. N. Pearson, Esq.); Prairie du Long, Illinois: Subcarboniferous.

PENTREMITES GODONI, var. MAJOR, *var. nov.*

(Pl. II. fig. 1.)

Remarks. We propose to distinguish our largest variety of *P. Godoni* under the above name. It differs so markedly from the smaller and shorter varieties, that, had it not been for the number of connecting links, we should have bestowed on it a distinctive specific name. There is a general resemblance to *P. Burlingtonensis*, M. & W., but the spiracles of the present specimen are single as in the typical *Pentremites.*

Locality and Horizon. Franklin County, Tennessee: Kaskaskia Limestone, Chester Group, Subcarboniferous. (Presented by Prof. T. R. Jones, F.R.S.)

PENTREMITES GODONI, var. FLOREALIS, *Schlotheim*, var.

(Pl. II. fig. 2.)

Asterial Fossil, Parkinson, Organic Remains, 1808, vol. ii. p. 235, t. 13. f. 36 and 37.
Encrinites florealis, Schlotheim, Petrefactenkunde, 1820, Abth. i. p. 339.
Pentremites florealis, Goldfuss, Petrefacta Germaniæ, 1836, Theil i. p. 161, t. 50. f. 2 *a–c*.

Remarks. Parkinson's "*Asterial Fossil*," and the *Encrinites florealis*, Schlotheim, seem to us from Parkinson's and Goldfuss's figures to be the equivalent of our third variety, in which the bodies of the radials are very much inclined to the vertical axis of the calyx. Should this supposition be correct, the trivial name *florealis* might be retained to distinguish this variety.

Locality and Horizon. Huntsville, Alabama: Chester Group, Subcarboniferous.

PENTREMITES GODONI, var. ABBREVIATUS, *Hambach*, var.

(Pl. II. fig. 4.)

Pentremites abbreviatus, Hambach, Trans. St. Louis Acad. Sci. 1880, vol. iv. no. 1, p. 155, t. B. f. 3.

Remarks. Mr. Hambach's species is thus described: "Body depressed, conoidal, wider than long; basal portion horizontal."

Four examples of this species were kindly sent to one of us by Prof. A. H. Worthen, and we have also had before us several specimens of *P. Godoni* which answer to the characters and resemble the figure of *P. abbreviatus*, while we have others intermediate between these, and undoubted examples of the typical *P. Godoni.* Under these circumstances we feel obliged to include *P. abbreviatus* as a variety of *P. Godoni.*

Locality and Horizon. Chester, Illinois: Chester Group, Subcarboniferous. (Presented by Dr. P. H. Carpenter, F.R.S.)

PENTREMITES ELONGATUS, *F. B. Shumard.*

(Pl. I. figs. 4, 5; Pl. II. figs. 14, 15; Pl. XVIII. fig. 4.)

Pentremites elongatus, Shumard, Swallow's 1st and 2nd Ann. Report, Geol. Survey Missouri, 1855, pt. 2, p. 187, t. B. f. 4.
Pentremites elongatus, Shumard, Trans. St. Louis Acad. Sci. 1858, vol. i. pt. 2, p. 244.
Pentremites elongatus, Lyon & Casseday, Proc. American Acad. 1860, vol. iv. p. 296.
Pentremites elongatus, White, Boston Journ. Nat. Hist. 1863, vol. vii. p. 488.
Pentremites elongatus, Shumard, Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 384.

Sp. Char. Calyx elliptical, elongated and attenuated upwards, from one and three quarters to twice as broad as long; summit convex and more or less contracted; base truncate but convex, small, but wider than the summit; section roundly pentagonal; periphery as nearly as possible equatorial. Basal plates small, forming a shallow expanded cup; projection of the columnar facet broad and low. Radial plates narrow and very long, quite two thirds the entire length of the calyx; bodies short and obliquely bent inwards, and subangular in the middle line; limbs with parallel margins, steep sides, and very obliquely truncated above; sinuses broadly lanceolate; lips rather prominent; interradial sutures in concavities. Deltoid plates acutely and unequally rhombic, and their surfaces concave; radio-deltoid sutures at about one third the height of the calyx from the summit. Ambulacra convex, extending nearly the entire length of the body, their proximal ends depressed below the edges of the sinuses, but on a level with them distally; lancet-plate as wide as, if not wider than, the combined side plates on each side; ambulacral grooves wide and shallow, but the lateral grooves slightly oblique; side plates oblong, forty to fifty in number. Three hydrospire-folds on each side. Spiracles oval, but often in pairs, and separated by strong septa. Mouth small. Ornament consists of fine lines parallel to the margins of the plates.

Remarks. The division of the four regular spiracles into eight apertures does not appear to be a constant character. We figure a specimen from Mr. Wachsmuth's collection (Pl. I. fig. 4) in which the spiracles are single, and the National Collection contains a similar example, as also one with double spiracles (fig. 5) like those of *P. Burlingtonensis.* It is noteworthy that these two species are the earliest known representatives of the genus, and that they approach *Mesoblastus* in the division of the spiracular openings. The details of the summit structure were not given in Shumard's original account of the type, nor by any later writer, but the relations of the pinnules were described by Dr. C. A. White in 1863, as we have remarked in our observations on the genus *Pentremites*[1].

Two well-marked varieties can be distinguished amongst the individuals of this species, but there are numerous connecting links between them.

[1] See *antea*, p. 153.

1. Calyx robust in every respect, and the base broader. (Pl. II. fig. 14.)

2. Calyx narrow and slim, both the summit and base more or less attenuated. (Pl. II. fig. 15.)

The first of these two forms appears to approach the more nearly to Shumard's original figure.

Locality and Horizon. Burlington, Iowa: Upper Burlington Limestone, Subcarboniferous.

PENTREMITES CONOIDEUS, *Hall.*

(Pl. II. figs. 16–23; Pl. III. figs. 4–12; Pl. XVIII. figs. 6–8.)

Pentremites conoideus, Hall, Trans. Albany Inst. 1856, vol. iv. p. 5; Iowa Geol. Report, 1858, vol. i. pt. 2, p. 655, t. 22. f. 8–10.

Pentremites Koninckana, Hall, Trans. Albany Inst. 1856, vol. iv. p. 4; Iowa Geol. Report, vol. i. pt. 2, p. 656, t. 22. f. 11, *a–c.*

Pentremites conoideus, Shumard, Trans. St. Louis Acad. Sci. 1858, vol. i. pt. 2, pp. 243 and 246, t. 9. f. 4.

Pentremites conoideus et *P. Koninckana,* Shumard, Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, pp. 383 and 384.

Pentremites conoideus, Billings, American Journ. Sci. 1869, vol. xlviii. p. 81. f. 15.

Pentremites sulcatus, Zittel, Handb. Pal. 1879, 1 Bd. 3 Lief. p. 432, f. 305 *a.*

Pentremites conoideus, White, in Collett's 2nd Ann. Report Dept. Stat. and Geol. Indiana, 1880, p. 512, t. 7. f. 12.

Pentremites conoideus, et *P. Koninckana,* Whitfield, Bull. American Mus. Nat. Hist. 1882, vol. i. no. 3, pp. 43 and 44, t. 9. figs. 32 and 33.

Pentremites conoideus, et *P. Koninckana,* E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 216.

Pentremites conoideus, et *P. Koninckana,* Hall, in Collett's 12th Ann. Report Dept. Geol. and Nat. Hist. for 1882 [1883], p. 323, t. 32. figs. 32 and 33.

Sp. Char. Calyx conoidal or pyramidal, gradually contracting upwards from the radial lips, but in the young state subglobose or subpyriform; summit more or less contracted or acuminate, but in the young condition blunt, convex, and relatively broad; base subtruncate or subpyramidal; section pentagonal, and very strongly so at the radial lips in the adult; periphery at the radial lips, though in the adult this line is but little above the subtruncate base. Basal plates forming a very shallow cup, almost flat internally, but in the immature condition the cup is moderately deep, and when viewed from below rather trilobate. Radial plates oblong, much arched transversely, a little less than two thirds the entire length of the calyx when fully grown; bodies small, nearly horizontal, and turned in to assist in forming the subtruncate base, but in the young state the bodies are inclined at a much sharper angle to the vertical axis of the calyx; limbs long and steep sided, their margins parallel and obliquely truncated above, but in the immature condition the limbs and bodies

are of about equal length; sinuses moderately wide, with bead-like margins; lips simple, and projecting but little; interradial sutures in concavities. Deltoid plates acutely and unequally rhombic, with concave surfaces, the hinder margins shorter than those nearer the summit, but in the young form the plates are simply lanceolate. Ambulacra convex, subpetaloid; lancet-plates of less width than the combined side plates, which number about forty, but in the young state are generally from ten to twenty. Four hydrospire-folds on each side. Spiracles triangular-ovate, closely placed round the mouth, which is small. Ornament of fine close striæ arranged as usual, but the striæ on the bands along the edges of the sinuses are stronger than the others.

Remarks. P. conoideus taken alone as originally described by Prof. J. Hall would not readily be mistaken for any other species. We follow Prof. R. P. Whitfield, however, in considering *P. conoideus* and *P. Koninckanus* as respectively the older and younger conditions of one and the same species [1]. He says, "The specimens described under this name (i. e. *Koninckana* [2])are probably the young of *P. conoideus*, Hall. All the variations between them are in the direct course of development by additional growth. The short base, almost flat in the older specimens, is one of the most prominent characteristics of *P. conoideus*, but among a large number of small specimens of the species from the different localities none are found with flat bases, but as they increase in size this feature becomes more and more apparent."

We have had the advantage of studying a very large series of both conditions of *P. conoideus*, and we altogether concur in the above remarks. In support of the union of Hall's two species we give a series of outline drawings of the younger stages of his *P. Koninckana* (Pl. II. figs. 19–23), leading by gradations to the conoidal outline of *P. conoideus* (figs. 16–18). As the shell grew the base shortened, and the ambulacra increased in length, whilst at the same time the summit became more acute.

As regards the adult stage, we again quote from Prof. Whitfield:—"This species differs from any of the many described from the Carboniferous rocks of America in the conoidal form of the adult specimens, though young shells are common which present nearly the form of *P. pyriformis*, Say, and others that closely resemble *P. elegans* and *P. symmetricus*, Lyon" [3].

Dr. Shumard described a somewhat different arrangement of the apical covering-plates in this species from that usually met with in the Blastoidea. Instead of the complete dome, composed of small but irregular polygonal plates, which has been usually noticed by authors, Shumard described each aperture at the summit as closed by six pentagonal plates, viz. a central large one and five smaller ones sur-

[1] Bull. American Mus. Nat. Hist. 1882, vol. i. no. 3, p. 44.

[2] We do not quite understand why Hall used a feminine termination for this specific name.

[3] *Loc. cit.* p. 45.

rounding it, and in each case forming a separate little dome[1]. Hambach[2] says, however, that Shumard's original specimen "does not show anything of the remarkable structure represented in the figure. It is a specimen from Spergen Hill, Ind., and a number of specimens from the same locality as well as those from Greencastle, Ind., also a small variety found in the upper layers of the Chester or Kaskaskia Limestone, frequently present the same appearance—which, however, is due to the oolitic character of the rock in which they are imbedded. This induced me to call them 'ovulum-like bodies.'"

We presume that we are correct in supposing the last "them" to refer, not to the specimens and variety which are included in the previous "they," but to "the minute plates of *Pentremites conoidens* (*sic*) described and figured by Shumard," of which Hambach makes mention on the page preceding that from which we have quoted. Not having seen Shumard's specimen, we can offer no opinion as to the accuracy of Hambach's statements respecting it. But so far as the central group of plates is concerned at any rate, we cannot help thinking that the analogies of *Elæacrinus*, *Granatocrinus*, *Orophocrinus*, and *Schizoblastus* are all in favour of Shumard's description, as we have remarked on p. 68.

It may be noted further that Mr. Billings[3] said:—"In a specimen of the same species sent me by Mr. Lyon, in which those plates are partly preserved, I find that there is a small pore in each of the five angles of the central aperture;" and he rightly added, that "the five ambulacral grooves enter the interior through these pores," the presence of which was independently and almost simultaneously suggested by Messrs. Meek and Worthen in the following words:—"We think it possible that small openings exist under this latter group of plates (*i. e.* central dome) at the upper terminations of the ambulacral furrows[4]."

It must not, however, be forgotten that McCoy had perhaps already observed similar openings, for in his description of the genus *Pentremites* he says, "I think I observe ocular pores at the oral ends of the ambulacra[5]." McCoy, however, referred to *Pentremites*, forms which we now know to be species of *Granatocrinus* (e. g. *Pentremites campanulatus*, *P. Derbiensis*, and *P. ellipticus*), but we do not think that these somewhat doubtful pores can have been "ambulacral openings;" for a covered summit is unknown in any British Blastoid.

Both *Pentremites conoideus* and its variety *Koninckanus* are remarkable for the large proportion of the hydrospire apparatus which is enclosed within the substance

[1] Trans. St. Louis Acad. Sci. 1858, vol. i. no. 2, p. 243, pl. 9. fig. 4.
[2] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, pp. 540, 541.
[3] Amer. Journ. Sci. 1869, vol. xlviii. p. 82; Ann. & Mag. Nat. Hist. 1870, vol. v. p. 265.
[4] Proc. Acad. Nat. Sci. Philad. 1869, p. 85.
[5] Brit. Pal. Foss. fasc. 1, 1851, p. 123.

of the radial plates. The consequence of this is that the hydrospire-folds appear much shorter on the inside of the plate than the ambulacrum does on the outside (Pl. III. figs. 5–9); and the markings representing the ambulacra on the internal casts do not reach much below the equator, although the external ambulacra are as long as the calyx (Pl. III. fig. 4). The way in which this is caused by an ingrowth of the sides of the radial sinus is well shown in Pl. XVIII. figs. 7, 8.

Locality and Horizon. Spergen Hill, Indiana: Warsaw Limestone, St. Louis Group, Subcarboniferous.

PENTREMITES SULCATUS, *Roemer*, sp.

(Pl. I. figs. 8–10; Pl. II. fig. 31; Pl. XVI. fig. 20; Pl. XVIII. fig. 5.)

Pentatrematites sulcatus, Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 354, t. 6. f. 10 *a–c*.

Pentatrematites sulcatus, Roemer in Bronn's Lethæa Geogn. Dritte Aufl. 1852–54, Theil ii. p. 282, t. 4'. f. 9, *a & b*.

Pentremites sulcatus, Shumard, Trans. St. Louis Acad. Sci. 1858, vol. i. no. 2, pp. 243 and 246; *ibid.* 1865, vol. ii. no. 2, p. 385.

Pentremites sulcatus, Lyon and Casseday, Proc. American Acad. 1860, vol. iv. p. 298.

Pentatremites sulcatus, Bronn, Klassen und Ordn. Thier-Reichs, 1860, Bd. ii. t. 23. f. 1 F–J.

Pentremites sulcatus, Dujardin & Hupé, Hist. Nat. Zooph. Échinod. 1862, p. 91.

Sp. Char. Calyx large, subglobose; summit truncate; peristome concave; base short and obtusely pointed; section strongly pentagonal, the very concave ambulacra with the concave interradial areas giving rise to ten re-entering angles; periphery almost equatorial. Basal plates large, forming a shallow expanded cup; interbasal sutures in slight concavities. Radial plates large, oblong, and very prominent, much arched; bodies less than a third the length of the limbs, subcarinate in the middle line; limbs moderately long, with high, sloping, and more or less concave sides, obliquely truncated above; interradial sutures in deep concavities; sinuses deep, subpetaloid, with very sharp erect margins; lips simple. Deltoid plates elongately rhombic, with sharp margins and a concave surface, and placed on a level with the summit; radio-deltoid sutures straight or slightly sigmoidal. Ambulacra deeply inserted in the sinuses, much curved longitudinally, surface concave, the sides right and left of the ambulacral groove sloping inwards towards the latter, except for a very narrow margin immediately below the edge of the sinus, which is nearly horizontal; lancet-plate equal in width to the two rows of the side plates; ambulacral groove wide and shallow, and the lateral grooves almost horizontal; side plates about sixty-five, large and oblong. Four or five hydrospire-folds on each side. Spiracles large, rhombic-pyriform; septa incomplete, their central ends being represented by rounded tubercles. Mouth small. Ornament of the usual character.

Remarks. P. sulcatus belongs to a well-defined section of the genus which contains

such species as *P. obesus*, Lyon [1]; *P. robustus*, Lyon [2]; *P. cervinus*, Hall [3]; *P. basilaris*, Hambach [4], &c. The first of these appears to differ from the present species in the greater length of the calyx, especially of the basal portion, the more acute, longer, and less truncate summit, and the somewhat less curved ambulacra. In *P. cervinus* the ambulacra expand much more outwards than they do in *P. sulcatus*, and the depth of the base from the radial lips downwards is greater, giving quite a different appearance to the lower part of the calyx.

According to Prof. Hall [5], *P. Cherokeeus*, Troost (MS.), is identical with *P. sulcatus*. We have no direct means of forming an opinion on this point, for we lack specimens not only of this species but also of many others about which we much desire to satisfy ourselves. We must leave intricate questions of synonymy like this to our American co-workers for solution, as any attempt on our part would be absolutely futile in the absence of the necessary material. We may, however, remark in passing that Hall's figure of *P. Cherokeeus* exhibits very small deltoid plates projecting above the summit, a feature quite at variance with Roemer's figure of *P. sulcatus*.

The number of hydrospire-folds which occur in this species appears to be somewhat variable. In the polished section, which is represented on Pl. XVI. fig. 20, five tubes appear on the left side of the ambulacrum and four on the other; while in the transparent section of the same calyx, which is shown on Pl. XVIII. fig. 5, there is an indication of a sixth tube on the left side. It is formed as a diverticulum of what appears to be the normal outermost (or fourth) tube of that side, but is evidently quite short, as it does not appear in the other section of the same ambulacrum (Pl. XVI. fig. 20).

The reduction of the number of hydrospire-folds at the distal end of the ambulacrum, and their enclosure within the radials, as in *P. conoideus*, is well shown on Pl. II. fig. 31. (See p. 95.)

Zittel has figured a section of the hydrospires in a species which he calls *Pentremites sulcatus*, Say [6]. We suspect, however, that it is really the *P. pyriformis* of Say, *P. sulcatus* being Roemer's species. At any rate his section is much more like that of our *P. pyriformis* (Pl. XVIII. fig. 3) than those of *P. sulcatus*, which have more hollowed ambulacra (Pl. XVI. fig. 20; Pl. XVIII. fig. 5), and also deep concavities in the interradial areas of the calyx; and these last are altogether absent in Zittel's figure.

By the kindness of Mr. Charles Wachsmuth we are able to figure a fine specimen

[1] Palæontological Report, Owen's 3rd Report Geol. Survey Kentucky, 1857, p. 469.

[2] Trans. St. Louis Acad. Sci. 1860, vol. i. no. 4, p. 629.

[3] Iowa Geol. Report, 1858, vol. i. pt. 2, p. 690.

[4] Trans. St. Louis Acad. Sci. 1880, vol. iv. no. 1, p. 159.

[5] Iowa Geol. Report, 1858, vol. i. pt. 2, p. 691.

[6] Handb. Pal. 1879, Bd. i. Lief. 3, p. 429, f. 301 *b*, p. 433, f. 306.

of this type which not only has the alternating covering-plates of the ambulacra preserved, but also shows traces of the dome covering the peristomial area and the spiracles (Pl. I. fig. 8). This structure has been described both by Shumard and by Hambach, whose observations have been already discussed on pp. 69, 70.

Locality and Horizon. Chester, Illinois: Chester group, Subcarboniferous.

PENTREMITES OBESUS, *Lyon.*

Pentremites obesus, Lyon, in Owen's 3rd Report Geol. Survey Kentucky, 1857, p. 469, t. 2. f. 1 *a–d.*

Remarks. A single large and imperfectly preserved specimen probably belongs to this species. It possesses a rather more slender form than that figured by Lyon, and the ambulacra are straighter. The plates are very thick, and the radio-deltoid sutures have the sigmoidal outline of those of *P. obesus.* There are over ninety-five pores on each side of an ambulacrum, but Lyon describes as many as one hundred and fifty.

Locality and Horizon. Unknown.

PENTREMITES PYRIFORMIS, *Say.*

(Pl. I. figs. 6, 7; Pl. II. figs. 24–30; Pl. XII. figs. 13, 15; Pl. XVIII. fig. 3.)

Pentremites pyriformis, Say, Journ. Acad. Nat. Sci. Philad. 1825, vol. iv. pt. 2, p. 294.
Pentremites pyriformis, Say, Zool. Journ. 1825, vol. ii. no. 7, p. 314.
Pentremites pyriformis, Troost, Trans. Geol. Soc. Pennsylv. 1835, vol. i. pt. 2, p. 229, t. 10. f. 8.
Pentremites pyriformis, Owen, American Journ. Sci. 1842, vol. xliii. p. 20, f. 3.
Pentatrematites pyriformis, Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 354, t. 5. f. 9 *a–c.*
Pentremites pyriformis, Hall, Iowa Geol. Report, 1858, vol. i. pt. 2, p. 693, t. 25. f. 16.
Pentremites symmetricus, Hall, *loc. cit.* p. 694, t. 25. f. 14.
Pentremites pyriformis, Billings, Geol. Survey Canada Reports, Decade iv. 1859, p. 20, f. 5 & 7.
Pentremites pyriformis, Dujardin & Hupé, Hist. Nat. Zooph. Échinod. 1862, p. 91.
Pentremites pyriformis, Shumard, Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 385.
Pentremites pyriformis, Billings, American Journ. Sci. 1870, vol. l. p. 228.
Pentremites pyriformis, Wachsmuth & Springer, Proc. Acad. Nat. Sci. Philad. 1879, t. 17. f. 5.

Sp. Char. Calyx pyriform, tapering to both extremities; summit truncate or somewhat convex, and more or less narrowed; base small and narrow; section pentagonal, with the sides quite flat; periphery at the radial lips, which vary in position. Basal plates forming a small cup, which is often rendered more prominent below by the adherence of the top stem-joint. Radial plates oblong, convex, lateral margins subparallel, slightly spreading; bodies of variable length, carinate in the middle line;

limbs nearly of equal length with, or longer than, the bodies, flat sided; sinuses wide, with sharp margins; lips simple, not projecting; interradial sutures on the flat sides, or sometimes in very slight concavities. Deltoid plates small, sharply lanceolate, externally not reaching quite to the summit, surface slightly concave. Ambulacra subpetaloid, flat, depressed below the edges of the sinuses; lancet-plate usually equal in width to the two series of side and outer side plates combined; side plates twenty to forty in number; inner line of sockets excavated out of both lancet-plate and side plates; pores large and triangular. Five to seven hydrospire-folds on each side. Spiracles closely surrounding the mouth, rhombic oval. Mouth moderately large. Ornament of fine lines as usual.

Remarks. In describing *P. pyriformis*, Say remarked—"Found in plenty in Kentucky, in the same localities, and intimately intermixed with the succeeding species (i. e. *P. Godoni*); it may be readily distinguished by the gradual attenuation of the pelvis and contiguous parts, from the tips of the emargination of the scapulæ, to the origin of the column[1]." We are unable to describe the difference between this species and *P. Godoni* in more expressive language.

Messrs. Dujardin and Hupé, following Roemer, were inclined to regard this species as a variety of *P. Godoni*, or at any rate as very closely related to it. We have investigated this question by the aid of a large amount of material, and do not find such intermediate gradations as would warrant a union of the two species. The minute structure of the ambulacra of *P. pyriformis* was carefully studied by the late Mr. Billings[2], whose description of it has been quoted already[3], and is well illustrated by figs. 1–3 on Pl. I.

P. pyriformis varies almost as much in the outline of the calyx as does *P. Godoni*. The largest condition appears to be the form which Hall has designated as *P. symmetricus* (Pl. II. fig. 24). In this variety that portion of the calyx lying between the summit and the apices of the ambulacra is twice the height of that between the latter and the stem facet. A similar disproportion exists in our figs 25, 26 of the same Plate, but on glancing at figs. 27–30 it will be observed that the basal portion of the calyx gradually becomes elongated, until in the form represented by fig. 30 the proportions are as nearly as possible equal. This point is also well seen in Roemer's figure of *P. pyriformis*[4]. From Say's expression[5] "pelvis gradually attenuated," we believe this to be the typical form of the species. The peripheral diameter of the calyx also appears to vary to some extent. It is greater in proportion to the height in the original of fig. 27 than in any of our other specimens.

Localities and Horizon. Chester, and Prairie du Long, Illinois; Cumberland

[1] Journ. Acad. Nat. Sci. Philad. 1825, vol. iv. pt. 2, p. 294.
[2] American Journ. Sci. 1870, vol. l. p. 228. [3] *Antea*, p. 60.
[4] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. t. 5. f. 9 *a*.
[5] Journ. Acad. Nat. Sci. Philad. 1825, vol. iv. pt. 2, p. 294.

Mountain, Tennessee; Huntsville, Alabama; and Alleghany Mountains: Chester group, Subcarboniferous.

Genus PENTREMITIDEA, *d'Orbigny*, 1849 (*emend. E. & C.* 1882).

Pentremitidea, d'Orb. (pars), Prod. Pal. Strat. 1849, tome i. p. 102.

Pentremitidea, d'Orb. (pars), Cours élément. Pal. et Géol. 1852, tome ii. fas. 1. p. 139.

Pentatrematites Truncati, Roemer (pars), Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 368.

Pentremites, Schultze, Denkschr. k. Akad. Wissensch. Wien, 1867, Bd. xxvi. Abth. 2, p. 223.

Pentremitidea (pars), E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 220.

Gen. Char. Calyx varying in outline from elongately clavate-pyramidal to pentagonal-obpyriform; summit truncate or convex; base usually long and conical. Number and disposition of the plates as in *Pentremites* proper, but the deltoids are inconspicuous, generally confined to the summit, and rarely visible in a side view. Basal plates convex, forming a more or less high cup, and frequently carinate. Radial plates always strongly lobate. Ambulacra narrow, and usually not greatly depressed within the radial sinuses; side plates lying on the lancet-plates so as to conceal them more or less completely. Spiracles usually large, and constructed like those of *Pentremites,* as are also the hydrospires. Anus confluent with the two spiracles at its sides to form a common anal spiracle; the anal deltoid plate sometimes rather larger than the others.

History and Remarks. The name *Pentremitidea* was proposed by M. Alcide d'Orbigny in 1849 for two Devonian Blastoids from Spain, which he believed to be peculiar in having a calyx composed of but two rows of plates, the basals and the radials. Roemer showed [1], however, that the two species in question—*Pentremitidea Paillettei*, de Verneuil, sp., and *P. Schulzii*, d'Arch. & de Vern., sp., are provided, like other Blastoids, with the third row of calyx-plates or deltoids. On these grounds, therefore, *Pentremitidea* has not been adopted by later writers on this interesting class. It appears, however, that *P. Paillettei*, in common with a considerable number of other forms, possesses peculiarities of calycular structure which separate it at once from *Pentremites*, as understood by us. We have in consequence rehabilitated d'Orbigny's name for such species, although it might be contended by some that an entirely new name would have been preferable in this case. We are therefore glad to find that our view has been accepted by such authorities as Messrs. Wachsmuth and Barris [2].

The calyx of *Pentremitidea* is either more slender and elongate than that of

[1] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. pp. 368, 369.

[2] Report Geol. Survey Illinois, 1883, vol. vii. p. 363; Proc. Davenport Acad. Nat. Sci. 1885, vol. iv. p. 93.

Pentremites (Pl. IV. figs. 9, 11), or else it approaches in outline to that of *Orophocrinus* (Pl. V. figs. 1, 9, 18; Pl. XVI. fig. 11). These apparently dissimilar forms possess in common a slender base, narrow ambulacra, and deltoid plates, which are almost or entirely limited to the summit. The side plates of the ambulacra lie directly upon, and in a great measure cover, the lancet-plates (Pl. IV. fig. 12; Pl. V. figs. 3, 4, 19), except in one species (Pl. IV. fig. 14). Such characters are diametrically opposed to those of the typical *Pentremites*, when represented by such species as *P. Godoni*, Defrance, sp., *P. sulcatus*, Roemer, and *P. pyriformis*, Say (Pl. I.).

The external form of the calyx seems to vary more in this than in any other genus of the Blastoidea. We can distinguish two fairly distinct types, the pyriform and the clavate respectively, which are connected by several intermediate gradations. The type species of the genus, *P. Paillettei* (Pl. IV. fig. 9; Pl. XIV. fig. 13) stands at one extreme of the series; and there is a gradual transition through *P. Lusitanica* (Pl. IV. fig. 11; Pl. V. fig. 20) to *P. Eifelensis* (Pl. V. fig. 1), and *P. Roemeri* (Pl. XVI. fig. 11). From these we pass on the one hand to the round-topped species which more or less resemble *Orophocrinus inflatus* and *O. pentangularis* (Pl. XV. figs. 1, 9), such for example as *P. angulata* (Pl. IV. fig. 13), *P. Gilbertsoni*, *P. Malladai*, and *P. similis* (Pl. V. figs. 9, 18; Pl. X. fig. 2); and on the other, through the different varieties of *P. clavata* (Pl. IV. fig. 18; Pl. V. figs. 3, 17) to *P. Wachsmuthi*, with its elongated radials and shorter base (Pl. V. fig. 6), and lastly, to such forms as *P.? leda* (Pl. V. fig. 12) which resemble some species of *Mesoblastus* (Pl. VI. fig. 12; Pl. VIII. fig. 1) both in general outline and in the appearance of the deltoids externally. In fact *P.? leda* and some of its allies in the American Devonian would have to be transferred to *Mesoblastus* if they should be found to possess the hydrospire-plate, which is so very characteristic of this genus (Pl. IV. fig. 4; Pl. VI. fig. 10).

These are exceptional species, however, for the deltoid plates of *Pentremitidea* are rarely visible externally in a side view of the calyx, being overlapped by the limbs of the radials as in *Tricœlocrinus* (Pl. XIX. fig. 13) and the other Troostoblastidæ (Pl. IV. figs. 11, 13, 18; Pl. V. figs. 3, 17, 20). They are just visible, however, in *P. Wachsmuthi* (Pl. V. fig. 6) and also in the specimen of *P. Paillettei* which was figured by Roemer [1]; while they are almost equally small in *Pentremites calycinus*, *P. gemmiformis*, and even in some varieties of *P. pyriformis* (Pl. II. figs. 29, 30).

The side plates of *Pentremitidea angulata* do not reach very far over the lancet-plate (Pl. IV. fig. 14); but as a general rule they cover it entirely, not even a median groove being visible on its surface (Pl. IV. figs. 12, 15; Pl. V. figs. 3–5, 19). Those of *P. Lusitanica* are of considerable size, and support large side plates which project beyond them and alternate with the pores (Pl. IV. figs. 12, 15; Pl. X. fig. 1).

The complexity of the hydrospire apparatus of *Pentremitidea* seems to be almost as variable as the outline of the calyx. *P. angulata* has but few slits (Pl. IV. fig. 14);

[1] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. T. iv. f. 17 *b*.

while in *P. clavata*, var. *Schultzei*, there are six folds, which are freely pendent into the body-cavity (Pl. V. figs. 3, 5), and in *P. Paillettei* there are eight (Pl. XVII. fig. 11), the uppermost of which seem to be cut out of the radials as in *Phænoschisma* and *Orophocrinus* (Pl. XVII. figs. 13–16).

Species. The following species are, we believe, referable to *Pentremitidea* :—

Pentremites acutangulus, Schultze. Middle Devonian ; Eifel.
Pentremitidea Americana, Barris. Upper (or Middle ?) Devonian ; North Michigan.
Pentremitidea angulata, E. & C. Lower Devonian ; Asturias, Spain.
Pentremites clavatus, Schultze. Middle Devonian ; Eifel.
Pentatrematites Eifelensis, Roemer. Middle Devonian ; Eifel.
Pentremites Fraiponti, Dewalque. Lower Devonian ; Belgium.
Pentremitidea Gilbertsoni, sp. nov. Lower Devonian ; Leon, Spain.
? *Pentatrematites gracilis*, Steininger. Middle Devonian ; Eifel.
? *Pentremites leda*, Hall. Upper (or Middle ?) Devonian ; West New York State.
Pentremitidea Lusitanica, E. & C. Lower Devonian ; Asturias, Spain.
Pentremitidea Malladai, E. & C. Lower Devonian ; Leon, Spain.
? *Pentatrematites planus*, G. & F. Sandberger. Middle Devonian ; Nassau.
Pentremitidea Roemeri, sp. nov. Middle Devonian ; Eifel.
Pentremitidea similis, E. & C. Middle Devonian ; Eifel.
Pentremitidea Wachsmuthi, sp. nov. Lower Devonian ; Leon, Spain.
Pentremitidea ? *Whidbornei*, sp. nov. Middle Devonian ; South Devon.

Distribution. Pentremitidea is limited to rocks of the Devonian Period, just as *Pentremites* is to the Carboniferous Limestone, and it may fairly be called the characteristic Devonian genus of Blastoids. For, unlike *Pentremites* (with the possible exception of *P. ovalis*, Goldf.), it occurs on both sides of the Atlantic, being well represented in Germany and Spain, and by single species in Belgium and Britain. It is limited in America to the Hamilton Group of the Upper (or Middle ?) Devonian, which contains at least two, and perhaps six, species. The only British species known occurs in the Plymouth Limestone of Middle Devonian age ; and if the *Pentatrematites planus* which has been described by G. & F. Sandberger from the "Stringocephalenkalk" of Nassau be a *Pentremitidea*, then the genus would also occur in the Middle Devonian of that part of Germany, which is limited by Barrois to this horizon. According to most authors, however, the limestones of the Eifel district which contain six species of *Pentremitidea*, are of Middle Devonian age. But in any case there are several species from the Lower Devonian. Apart from the six in the "Eifeler Kalk," we know of seven from the Lower Devonian of Spain, one of which (*P. clavata*) is common to the Eifel beds. According to Barrois[1] these are at a slightly higher horizon than the "Calcaire d'Arnao" of the Asturias ; and one of the species in this bed (*P. Paillettei*) is also found both in

[1] Mém. Soc. Géol. du Nord, 1882, tome ii. Mém. 1, p. 518.

the Calcaire de Ferroñes below, and in the Calcaire de Moniello above, the latter, in his opinion, representing the Eifeler Kalk of Germany. The earliest known species, however, is *Pentremitidea Fraiponti* from the Grès de Gâhard (Taunusien) of Belgium.

Mr. Wachsmuth's collection contains a specimen of *P. Paillettei* (Pl. IV. figs. 9, 10) which he had obtained from a dealer, who gave its locality as Charleston, Indiana. He tells us, however, that none of the local collectors have ever met with a similar one, and it is therefore very doubtful whether the species really does occur in America at all [1]. We do not think it at all probable that this is the case, as we know of no Blastoids which are common to both sides of the Atlantic.

Type. Pentremites Pallettei, de Verneuil.

PENTREMITIDEA PAILLETTEI, *de Verneuil*, sp.
(Pl. IV. figs. 8–10; Pl. XIV. fig. 13; Pl. XVII. fig. 11.)

Pentremites Pailletti, de Vern. Bull. Soc. Géol. France, 1844, tome i. p. 213, t. 3. ff. 4, 5.
Pentremites Pailletti, d'Archiac & de Vern. *ibid.* 1845, tome ii. p. 479, t. 15. ff. 10 *a, b,* 11 *a, b.*
Pentremitidea Paillettei, d'Orbigny, Prod. Pal. Strat. 1849, tome i. p. 102.
Pentatrematites Pailleti, Roemer (pars), Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 368, t. 7. f. 17 *a–c*.
Pentremites Dutertrii, Roemer, *ibid.* p. 374.
Pentatremites Paillettei, Bronn, Klassen und Ordn. Thier-Reichs, 1860, Bd. ii. t. 23. f. 2 *a–c*.
Pentremites Pailletti, Dujardin & Hupé, Hist. Nat. Zooph. Échinod. 1862, p. 97, t. 2. f. 13.
Pentremites Pailleti, Mallada, Bol. Com. Mapa Geol. España, 1875, tomo ii. p. 78, *Ibid.* 1877, tomo iv. lám. 12. f. 5, 6.
Pentremitidea Pailletti, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 223.

Sp. Char. Calyx clove-shaped, expanding gradually upwards; base elongate and pointed; summit semitruncate, contracted towards the centre; periphery quinquelobate. Basal plates very long, longer than the radials, forming a slender elongate cup, the surface plane, and without a fold. Radial plates elongate, narrow, strongly arched in the middle line from the lip downwards, but not carinate; bodies occupying by far the greater portions of the plates, the limbs being short and insignificant; sinuses short, wide, open, and with a low radial angle; lips simple, not overhanging. Deltoid plates often invisible externally [2]. Ambulacra short, scarcely petaloid, retaining their width undiminished; side plates fifteen, and perhaps more, on each side of an ambulacrum [d'Archiac and de Verneuil say eighteen], transversely oblong; outer side plates unknown. Spiracles very minute, elongated openings separated by the deltoid ridge. Hydrospires eight on each side of an ambulacrum; tubes long; sacs pyriform. Mouth very small. Anal spiracle ovate-triangular, acutely pointed inwards. Orna-

[1] Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 223, and 1883, vol. xi. p. 226.

[2] We have not been able to make out the radio-deltoid sutures at all distinctly in any of our specimens. But Roemer seems to have been more fortunate; and his figures show that they just appear externally, while the anal deltoid is larger than its fellows as in *Troostocrinus*.

ment of fine thread-like striæ, parallel to the margins of the plates. Column of very minute joints.

Remarks. *Pentremitidea Paillettei* may be regarded both as the type of the genus and as the representative of its pyriform species. There is a gradual transition from *P. Paillettei* through *P. Lusitanica* (Pl. V. fig. 20) and *P. Eifelensis* (Pl. V. fig. 1) to the equally typical calyx of *P. clavata* (Pl. IV. fig. 18). The very pentalobate character of the calyx, when seen in section, is a striking feature of this species (Pl. IV. figs. 8, 9), and is more pronounced than in its nearest allies *P. Lusitanica* (Pl. IV. fig. 12) and *P. Eifelensis* (Pl. V. fig. 2), especially the latter. The ambulacra and radial sinuses are relatively much shorter than in the former type, and the radial angle differs a good deal (Pl. IV. figs. 9, 11). The calyx is also more slender, and lacks the distension visible in *P. Lusitanica* just below the lips of the radial plates; while the general form and the wider sinuses separate *P. Paillettei* from *P. Eifelensis* (Pl. V. figs. 1, 2).

Owing to a curious error the former species has been referred to as *Pentremites Dutertrii* in Roemer's well-known Monograph [1]. He gives as a reference L'Institut, 1844, xii. p. 216, but we find that the Blastoid mentioned on this page is really *P. Paillettei*, the name *Dutertrii* being employed for a species of *Leptæna.*

Locality and Horizon. Colle near Sabero, province of Leon, Spain: Calcaire d'Arnao, Lower Devonian. [De Verneuil and Barrois [2] also give Ferroñes, Asturias, in the Calcaire de Ferroñes, and the latter further mentions Luanco, in the Calcaire de Moniello.]

PENTREMITIDEA LUSITANICA, *E. & C.*

(Pl. IV. figs. 11, 12, 15; Pl. V. fig. 20; Pl. X. fig. 1.)

Pentremitidea Lusitanica, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 223.

Sp. Char. Calyx clavate-pyriform, elongate, expanding gradually upwards; base elongate and pointed; summit truncate. Basal plates only a trifle shorter than the radials, forming an elongated cup, the lower portion of each plate bearing a strong central ridge, which assists in forming the ornamentation, but a transverse fold is not present. Radial plates rather narrow, elongate, and arched from the lips downwards along the body of each plate; three impressed lines diverge from each lip, one to each infero-lateral angle, and one along the middle line; sinuses with sharp erect margins, making an angle of about 134° with the truncated summit; lips a little thickened and simply rounded. Ambulacra elongately petaloid; lancet-plates broad, almost wholly filling up the sinuses; side plates large and oblong, their outer margins rounded, about fifteen on each side of an ambulacrum; outer side plates narrow, bent down at a much greater angle than the side plates. Spiracles mere elongated slits; anal spiracle rounded, or inclined to circular. Ornament of fine

[1] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. ii. p. 374.

[2] Mém. Soc. Géol. du Nord, tome ii. Mém. 1, p. 225.

close raised lines parallel to the margins of the various plates, those on the lower portions of the basal plates being of a V-shaped pattern. Column unknown.

Remarks. This is a well-marked species, which may be at once distinguished from *Pentremitidea clavata*, Schultze, sp. (Pl. IV. fig. 18), and from the majority of the other species, by the outline of the calyx. It differs sharply from *P. Paillettei* in the lobation of the radials, the smaller angle of inclination of the sinuses, and in their relatively shorter length. *P. Lusitanica* to a certain extent resembles *P. Eifelensis*, Roemer, sp., of which Schultze has given a figure. Indeed, this species is its nearest ally; but here, again, the radial angle is quite different, and gives to the Eifel species the appearance of possessing a longer and more curved sinus in each radial, and a very much less breadth across the summit (Pl. V. figs. 1, 2).

Locality and Horizon. Ferroñes, Province of Asturias, Spain: Calcaire de Ferroñes, Lower Devonian.

Pentremites Eifelensis, *F. Roemer*, sp.
(Pl. V. figs. 1, 2.)

Pentatrematites Pailleti (pars), F. Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 368.

Pentatrematites Eifeliensis, F. Roemer, Bronn's Lethæa Geogn. Dritte Aufl. 1852–54, Theil 2, p. 280 (footnote).

Pentremites Eifeliensis, Schultze, Denkschr. k. Akad. Wissensch. Wien. 1867, Bd. xxxvi. Abth. 2, p. 223, t. 13. f. 5 *b*, *c* (? f. 5, 5 *a*, *d*, *e*).

Pentatrematites Eifeliensis, F. Roemer, Lethæa Geogn. 1876, Theil 1, Atlas, t. xxvii. f. 18 *a*, *b*.

Pentremitidea Eifelensis, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 223.

Sp. Char. Calyx small, elongately pyriform: summit small, gently convex, peristome concave; base slender, oval above, but becoming triangular below, with flattened sides, forming almost one half the total length of the calyx; section pentagonal; periphery at the radial lips less than a third the total length of the calyx from the summit. Basal plates small, elongate, convex in their upper portions, angular and subcarinate below. Radial plates oblong, much arched transversely, each about equally divided into body and limbs, or perhaps the latter a little the longer; interradial sutures in concavities; sinuses half the length of the radial plates, margins straight, simple, and subparallel; lips plain, not enlarged or much projecting. A line drawn transversely through the lip indicates the widest part of each plate. Ambulacra straight, projecting direct from the summit, not curved, and depressed below the edges of the sinuses; lancet-plates completely covered by the side plates, which are not numerous (probably from fifteen to twenty); pores few and large. Hydrospires unknown; spiracles small, heart-shaped, placed close around the mouth, which is also small. Column unknown. Ornament of fine microscopic lines parallel to the outline of the plates.

Remarks. P. Eifelensis was originally described by Prof. Roemer as an example of

P. Paillettei from the Eifel, though he subsequently separated it from the Spanish type by its present specific name. It was, however, never described until the publication of Schultze's 'Monographie der Echinodermen des Eifler Kalkes,' in which two lateral and two summit views of it are shown. We do not think, however, that the two individuals which are figured can properly be referred to the same species. The original of figs. 5 *b* and 5 *c* is most like *P. Paillettei*, and must therefore be considered the type of the species. There is a nearly similar individual in the National Collection (Pl. V. figs. 1, 2); but apart from the characters which are mentioned by Roemer and Schultze, its five large spiracular openings sharply distinguish it from *P. Paillettei* (Pl. IV. figs. 8, 10), and also from *P. Lusitanica*, which it more closely resembles in the external form of the calyx (Pl. IV. figs. 11, 12; Pl. V. fig. 20).

Prof. Roemer has kindly sent us two specimens of *P. Eifelensis* for examination, and we find that they represent the two types figured by Schultze, but we cannot refer them to the same species. We propose therefore to restrict the name *P. Eifelensis* to the more flat-topped form which resembles *P. Paillettei*, and to describe the other in another place [1] by the name *P. Roemeri*. It is figured on Pl. V. fig. 13, and Pl. XVI. fig. 11, and also on Taf. xiii. figs. 5, 5 *a* of Schultze's Monograph.

The latter author thought that he could trace a considerable resemblance between the radials of *Pentremitidea Eifelensis* and those of *Pentremites obliquatus*, Roemer, when the truncation of their lower ends in the American species was left out of consideration. Apart from the larger size of the radials in this type (Pl. XVIII. figs. 10–12), their ambulacra are relatively much narrower than those of *Pentremitidea Eifelensis*, and the character disregarded by Schultze is one of those which are specially distinctive of the genus *Tricœlocrinus* (Pl. XIX. fig. 13), while the radials of the German species are transversely arched. We think therefore that there will be no chance of any confusion of the two types.

Locality and Horizon. Gerolstein: Eifel Limestone, Middle Devonian (*auctorum*), or Lower Devonian (*Barrois*).

Pentremitidea Malladai, *E. & C.*
(Pl. V. figs. 18, 19.)

Pentremitidea Malladæ, E. & C., Ann. & Mag. Nat. Hist. 1883, vol. xi. p. 243.

Sp. Char. Calyx pentagono-pyramidal, expanding gradually upwards; summit truncate and relatively large, diameter 7·5 millim.; section pentagonal, with wide and shallow reentering angles between the ambulacra; periphery at about one third of its length from the summit. Basal plates forming a strong broad and deep cup. Radial plates quadrangular, the bodies slanting sharply downwards, and rather shorter than the limbs, which curve upwards towards the summit, thus increasing its apparent breadth; lips projecting; sinuses long, narrow, and curved downwards, with a radial angle of 111°. Ambulacra narrow, of nearly uniform width throughout;

[1] In the columns of the 'Geological Magazine.'

lancet-plates small, scarcely occupying the entire width of the sinuses; side plates about fifteen in number, large and strong, projecting above the margins of the sinuses, and somewhat petaloid in shape. Deltoid plates almost entirely concealed by the radial limbs, each showing but little more than a well-marked median ridge, which partially separates the spiracles at its sides. Mouth of moderate size. Ornament of strong and coarse concentric lines. Column unknown.

Remarks. The outline of the calyx readily distinguishes this species of *Pentremitidea* from the three which were obtained from the Eifel Limestone by Schultze. It is pyramidal from the base to the radial lips, while the latter are clavate and obpyriform. Its pentagonal section will prevent its being confounded with the decagonal *P. angulata*, nobis (Pl. IV. fig. 14), which has the interradial sutures raised, and not depressed as in *P. Malladai* (Pl. V. fig. 19). The latter has smaller deltoids than *P. similis*, nobis (Pl. V. fig. 16), while its calycular outline is also different. The longer, narrower, and more curved ambulacra and shorter base separate it from *P. Lusitanica* (Pl. V. fig. 20); while, on the other hand, it has not the broadly truncated summit and narrow elongated base of *P. Paillettei* (Pl. IV. fig. 9).

When originally describing *Pentremitidea similis* (Pl. X. figs. 2, 4) we noted the resemblance in the general form of its calyx to that of *Orophocrinus*. *P. Malladai*, on the other hand, exhibits a digression towards *Codaster*; for the pyramidal outline of the calyx is not at all unlike that presented by *C. Hindei*, nobis (Pl. XII. figs. 5, 6), and even more like that of *C. pyramidatus* (Pl. XII. figs. 2, 3).

We have connected the name of this species with that of Don Lucas Mallada, of the Spanish Geological Survey, to whom we are indebted for the opportunity of describing both it and also some other species from Spain.

Locality and Horizon. Colle, near Sabero, Province of Leon, Spain: Calcaire d'Arnao, Lower Devonian. (Presented by Dr. P. H. Carpenter, F.R.S.)

Pentremitidea clavata, *Schultze*, sp.
(Pl. IV. figs. 17, 18; Pl. V. figs. 3–5, 17.)

Pentremites clavatus, Schultze, Denkschr. k. Akad. Wissensch. 1867, Bd. xxvi. Abth. 2, p. 225, t. 13. f. 7 *a–e*.

Pentremitidea clavata, E & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 223.

Sp. Char. Calyx club-shaped; base funnel-like, rapidly attenuating and triangular; summit contracted, small, and concave; periphery almost equatorial where the sides of the pentagon are flat or slightly concave. Basal plates carinate in the middle line. Radial plates oblong quadrangular, their surfaces in two planes, the upper sloping away to the summit, and consisting of the limbs, which are more than double the length of the bodies; the second plane in each plate is formed by the bodies below the lips, and is concave or hollowed out; interradial sutures not placed in depressions; apices or proximal ends of the limbs prominent and sometimes pro-

jecting slightly upwards above the concave summit; sinuses long, narrow, and much bent down at their distal extremities; lips not individually prominent, but projecting on account of the natural convexity of the radial plates about the periphery; radial angle 89°. Deltoid plates quite inconspicuous. Ambulacra moderately narrow, retaining the same width throughout the greater portion of their length; food-groove very distinct, deep, and moderately wide; side plates at least twenty-six in number on each side of an ambulacrum, square to oblong in form; outer side plates very minute. Spiracles round, and large for the size of the calyx, situated within the circumscribed depression of the summit, and often with well-marked septa; anal spiracle pyriform-triangular. Hydrospires unknown in the species proper. Mouth large. Ornament of rather coarse concentric lines. Column unknown.

Remarks. This species is remarkable for its occurrence in the Eifelien division of the Devonian both in Spain and in Germany[1]. In fact, with the exception of *Orophocrinus pentangularis*, which occurs in the Carboniferous Limestone of England, Ireland, and Belgium, it is the only Blastoid which has been found in more than one country of Europe.

The shape of its calyx readily distinguishes it from *Pentremitidea angulata* which has a decagonal section (Pl. IV. figs. 13, 14); while the sides of the calyx in *P. clavata* are flattened or concave (Pl. IV. figs. 17, 18; Pl. V. fig. 17). One of its most striking characters, in which it approaches *P. Wachsmuthi* and *P.* ? *leda* (Pl. V. figs. 6, 12), is the deep incision of the radials and the consequent great length of the ambulacra, both points in which it is allied to *P. acutangula*, Schultze, sp., which we have unfortunately been unable to see. This is most marked in young individuals, which have almost no bodies to the radials at all, as is well shown in Schultze's figures[2]. The shape of the upper part of the calyx also seems to vary a good deal, and we have no Spanish examples in which it is quite so rounded as is represented in Schultze's figures and in our Pl. IV. fig. 18. But the form shown on Pl. V. fig. 17 is not very different from his largest variety shown in fig. 7, and we have a smaller one with a summit quite as round as the original of his fig. 7*a*.

Localities and Horizon. Nollenbach, near Kerpen: Eifel Limestone, Middle Devonian (*auctorum*), but Lower Devonian (Barrois). Colle, near Sabero, Province of Leon, Spain: Calcaire d'Arnao, Lower Devonian. (Presented by Dr. P. H. Carpenter, F.R.S.)

PENTREMITIDEA CLAVATA, var. SCHULTZEI, *E. & C.*, var. nov.

(Pl. V. figs. 3–5.)

We propose to give this varietal name to a Spanish form which we do not feel justified in separating from Schultze's type, though it differs from it much more

[1] Most authors consider the Eifel Limestone as of Middle Devonian age, but Barrois places it in the Lower Devonian.

[2] Denkschr. k. Akad. Wissensch. Wien, 1867, Bd. xxvi. Abth. 2, t. 13. f. 7 c.

than other examples from the same locality do (Pl. V. fig. 17). The ambulacra are narrower, longer, and also straighter than in the Eifel specimens, while the summit is also much more constricted (Pl. IV. figs. 17, 18; Pl. V. figs. 3, 4). Except in the latter point it somewhat resembles *P. Americana*, Barris [1]; but the radial sinuses of this type are rather wide and their edges slope down towards the ambulacra as in *P. Lusitanica* (Pl. IV. figs. 11, 12), which is by no means the case in any forms of *P. clavata* (Pl. IV. figs. 17, 18; Pl. V. figs. 3–5, 17).

The figured specimen of this variety is a good deal weathered, and it shows how the lancet-plate is completely covered by the side plates, and in its turn conceals the hydrospires, which are fully visible at the distal end of the sinus, not being received into the body of the radial, as is so often the case in *Pentremites* (Pl. V. figs. 3, 4); while in fig. 5 the hydrospires are seen depending into the visceral cavity.

Locality and Horizon. Colle, near Sabero, in the Province of Leon, Spain: Calcaire d'Arnao, Lower Devonian. (Presented by Dr. P. H. Carpenter, F.R.S.)

Pentremitidea Wachsmuthi, sp. nov.

(Pl. V. figs. 6–8.)

Sp. Char. Calyx bud-like, or oblong-clavate; summit convex, but contracted and narrow; peristome concave; base short and triangular; section somewhat roundly pentagonal, the sides becoming gently concave about the basiradial suture; periphery equatorial, or perhaps a little nearer the base. Basal plates angular, acutely so below, forming a short trihedral cup; interbasal sutures on the flat sides, neither on prominences nor in depressions. Radial plates oblong, nearly parallel-sided; bodies small; limbs narrow, four times as long as the bodies; sinuses very long and narrow, with rim-like margins, arching closely downwards; lips moderately prominent; radial angle 92°. Deltoid plates very small, horizontal, or inclined inwards towards the peristome, but sometimes just visible in a side view. Ambulacra moderately narrow, not inflated, nor arching outwards from the sides of the calyx, but appressed to the latter, and depressed below the edges of the sinuses; side plates thirty and probably more; ambulacral grooves broad and shallow at their proximal ends. Hydrospires unknown; spiracles large and oval, closely situated around the mouth, and occupying by far the larger portion of the deltoid plates. Mouth small. Column and ornament unknown.

Remarks. This is a peculiar and well-defined species and may be at once recognized by the short base, with the long and closely appressed ambulacra, which impart to the calyx a very bud-like appearance (Pl. V. fig. 6). It is clearly related to the group represented by *Pentremitidea acutangula*, Schultze, sp., but is distinguished from it by the shortness and the more vertical position of the bodies of the radials. In fact,

[1] Report Geol. Survey Illinois, 1883, vol. vii. p. 363; and Proc. Davenport Acad. Nat. Sci. 1885, vol. iv. p. 93, pl. i. fig. 4.

it may be stated generally that this point will separate *P. Wachsmuthi* from all species of the genus known to us. In some respects it is not unlike *P. Americana*, Barris, but it lacks the wide radial sinuses of that type. Specimens are frequently met with broken short off at the basiradial suture, when, if care be not taken, they might at a casual glance be mistaken for examples of *Granatocrinus*.

It affords us very great pleasure to name this species after Mr. Charles Wachsmuth, to whom we are greatly indebted for most valuable assistance in our study of the Blastoidea.

Locality and Horizon. Colle, near Sabero, Province of Leon, Spain: Calcaire d'Arnao, Lower Devonian. (Presented by Dr. P. H. Carpenter, F.R.S.)

Pentremitidea Gilbertsoni, sp. nov.

(Pl. V. figs. 9–11.)

Sp. Char. Calyx obtusely clavate, suddenly enlarging upwards above the basiradial sutures; summit small, contracted, and considerably hollowed; peristome very concave; periphery nearly equatorial, rather nearer the summit than the base. Base triangular and tricarinate, with the sides flattened, or slightly concave. Basal plates convex or arched above, carinate below, forming a strong expanded cup; interbasal sutures in slight concavities. Radial plates large, oblong, their surfaces in two planes which cut one another at a line drawn through the radial lips; the lower portion or body of each plate is small and concave, the limbs are long and much arched; sinuses narrow, sides subparallel and a little thickened; lips prominent; interradial sutures in slight concavities. Deltoid plates quite small, assisting to form the contracted summit, and just visible in a side view. Ambulacra much curved, quite half the length of the calyx, projecting above the edges of the sinuses; lancet-plates just visible in the median line for about half the length of the ambulacra; side plates from twenty to thirty; pores large. Hydrospires unknown; spiracles large, oval pyriform. Column and ornament not preserved.

Remarks. This species is remarkable from the sudden inflation of the calyx immediately above the basiradial sutures. Owing to this character and to the length of the curved ambulacra it has a top-heavy appearance. There is a certain amount of resemblance between *P. Gilbertsoni* and *P. angulata* (Pl. IV. figs. 13, 14), but one is pentagonal in section and the other decagonal. The inflation of the calyx in *P. acutangula* is greater than in the present species, and its base is also smaller; but there is much resemblance between *P. Gilbertsoni* and a very young *P. clavata* figured by Schultze[1]. We name this interesting species in memory of one of the earliest collectors of British Blastoids.

Locality and Horizon. Colle, near Sabero, Province of Leon, Spain: Lower Devonian. (Presented by Dr. P. H. Carpenter, F.R.S.)

[1] Denkschr. k. Akad. Wissensch. Wien, 1867, Bd. xxvi. Abth. 2, taf. xiii. fig. 7c.

PENTREMITIDEA ANGULATA, *E. & C.*

(Pl. IV. figs. 13, 14, 16.)

Pentremitidea angulata, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 224.

Sp. Char. Calyx pentagonal-obpyriform; summit small; section decagonal above, without reentering angles between the ambulacra, but triangular at the base; periphery equatorial. Basal plates a little less than half the length of the radials, forming a strongly trihedral cup, with three prominent angles, one interradial and the two others radial; surface of the plates between the angles hollowed out. Radial plates elongate, their surfaces in two planes, which cut one another at the equatorial line of the calyx; the upper, sloping away to the summit, consists of the limbs; the lower, or the body below the lips, extends to the basiradial sutures and is hollowed out on each side, a median ridge passing downwards from the lips to the basiradial sutures, whilst the angle produced by the union of the two planes forms the periphery or equator of the calyx; interradial sutures not placed in depressions but forming the five additional angles of the calyx; sinuses narrow and long, their distal extremities being equatorial; lips prominent. Deltoid plates quite apical. Ambulacra rather long and very narrow, maintaining almost the same width throughout their whole course; lancet-plates nearly as wide as the sinuses and partially visible in the middle line; side plates about twenty in number on each side of an ambulacrum, short but broad. Spiracles close round the mouth; anal spiracle with a prominent outer margin. Ornament of fine lines parallel to the margins of the plates. Column unknown.

Remarks. This is a very interesting and peculiar species, and represents together with that next to be described one extreme type of the genus. The form of the calyx, and the angulation of the radial plates will readily separate *P. angulata* from all the described species. The abruptly clavate outline indicates an approach to *P. clavata*, Schultze, sp. (Pl. IV. fig. 18); but no other resemblance is observable; whilst with *P. similis*, nobis (Pl. X. fig. 2), although after the same general type, no definite comparison can be made, as the latter has a longer and more tapering base, and hollow interradial areas. There is a curious resemblance in external form between *Pentremitidea angulata* and *Phænoschisma caryophyllatum*, de Kon. & le Hon, sp. (Pl. XIV. fig. 4), a member of a distinct genus that differs altogether from *Pentremitidea* in its other characters. *Pentremitidea angulata* is the aberrant species of the one genus as *Phænoschisma caryophyllatum* is of the other. Both agree to a certain extent in outward form, and differ in this particular from the other species of their respective genera.

Locality and Horizon. ? Ferroñes, Province of Asturias, Spain: Lower Devonian.

PENTREMITIDEA SIMILIS, *E. & C.*

(Pl. V. fig. 16; Pl. X. figs. 1–3.)

Pentremitidea similis, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 225.

Sp. Char. Calyx pentagonal-obpyriform, expanding rapidly upwards above the

basiradial sutures; summit depressed; base sharp; section strongly pentagonal; periphery nearer the summit than the base. Basal plates forming a small, slightly expanded cup. Radial plates arched, broad at their bases, expanding very slightly upwards to the level of the lips; the limbs then rapidly decrease towards the summit, and form strong projecting lobes around it; sinuses straight and very narrow; radial angle about 134°. Deltoid plates almost invisible. Ambulacra narrow.

Remarks. Although we can only give a limited definition of this species, it is nevertheless sufficient to show how clearly distinct the type is from any other *Pentremitidea*. On the other hand, the resemblance of the calyx in general form to that of an *Orophocrinus*, especially in the typical species *O. stelliformis*, O. & S., sp. (Pl. XVI. figs. 5, 7), and in *O. verus* (Pl. XV. fig. 3), is very remarkable; but here, of course, the resemblance ceases. The radial angle, the length of the ambulacra, and the greater amount of calycular surface between their distal extremities and the base of the calyx in *P. similis*, separate it from *P. clavata*, Schultze, sp. (Pl. IV. fig. 18), to which it is nearly related. The form of the radial plates in *P. angulata* (Pl. IV. fig. 13), irrespective of other characters, at once separates the latter from *P. similis*.

The Messrs. Sandberger have described[1] a peculiar form from the Rhenish Devonian rocks (*Pentatrematites planus*), which we believe to be an aberrant *Pentremitidea*, but it is much too depressed a species to be confounded with ours. There is another Eifel species which has received from Dr. J. Steininger the name of *Pentremites gracilis*[2], but the meagre description given renders it quite impossible for us to form any idea of what it may be like, a difficulty which has been already noticed by Prof. F. Roemer[3]. It is also a noteworthy fact that Schultze does not record Steininger's species in his well-known Monograph of the Eifel Echinoderms.

Locality and Horizon. Prüm: Eifel Limestone, Middle Devonian (*auctorum*), but Lower Devonian (Barrois).

Genus MESOBLASTUS[4], gen. nov.

Granatocrinus (pars), E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 236.

Gen. Char. Calyx generally resembling that of *Granatocrinus* in the form and proportions of its component parts. The base is concave or protuberant. The radial plates are long, and the deltoid plates small, short, and unequally rhombic[5]. Spiracles distinctly double as a rule, but sometimes incompletely divided. Their distal border is formed by side plates which rest in the angle between hydrospire-plate and lancet-plate, and almost or entirely conceal the latter. Hydrospire-folds few in number (more than three?). Posterior spiracles confluent with anus.

[1] Verstein. Rhein. Schichten Nassau, 1850–56, p. 403, Atlas, t. 25. fig. 4*a* & *b*.

[2] Jahresb. Schul-Cursus, 1848–49, Gymn. zu Trier, 1849, p. 19.

[3] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 374.

[4] μέσος, intermediate.

[5] *i. e.* so far as the species are known to us.

History. The species now placed in *Mesoblastus* were formerly included by us in *Granatocrinus*, as we then understood that genus. At the time we wrote, however, we found considerable difficulty in satisfactorily disposing of several species, which did not in all their characters conform to our emended view of *Granatocrinus.* The species in question were *Mitra elongata*, Cumberland (=*Pentatrematites oblonga*, G. B. Sby.), *Pentatrematites crenulatus*, Roemer, *P. angulata*, G. B. Sby., and an undescribed form which we now propose to call *Mesoblastus Sowerbii.*

Remarks. In almost every particular but one this group agrees with *Granatocrinus*, so far as we are acquainted with the structure of the species composing it. But in the relations of its spiracles it is more closely allied to *Pentremites* proper, as the genus is now restricted. In other words *Mesoblastus* has the same outline and disposition of the component parts of the calyx as occur in *Granatocrinus*, but its spiracles are constructed on a totally different plan from those of this genus. For the hydrospire-canals do not open externally by piercing the deltoid plates (Pl. VII. figs. 5–7), but they are continued upwards over the flattened lateral portions of these plates and open at the sides of their central ridge, just as in *Pentremites Godoni* and *P. elongatus* (Pl. I. figs. 5, 11), though this ridge is occasionally incomplete (Pl. IV. fig. 1; Pl. VIII. fig. 4). In *Mesoblastus*, as in the other Pentremitidæ, the hydrospire-cleft is converted into a canal by a roof of side plates, which thus form the distal border of the spiracle (Pl. VI. figs. 8, 13). But the cleft is not laid open when the side plates are removed, as is the case in *Pentremites* (Pl. I. fig. 5); for it has an inner roof formed by the hydrospire-plate, which meets the wall of the sinus and helps to support the side plates (Pl. IV. fig. 4; Pl. VI. fig. 10; Pl. VIII. fig. 6).

It will be evident from the foregoing remarks that *Mesoblastus* is altogether different from *Schizoblastus*, the type which we separated from *Granatocrinus* in 1882. *Schizoblastus* has no hydrospire-plate, and its spiracles are minute slits between the deltoids and lancet-plate, which generally fills up the radial sinus so that the side plates do not project beyond its edge and roof in the hydrospire-canal (Pl. XVI. fig. 12).

The calyx in *Mesoblastus* may be generally described as elongate, but it is least so in *M. crenulatus*, Roemer, sp. The base is either concave, as in *M. elongatus* and *M. angulatus* (Pl. VIII. figs. 3, 8), or protuberant, as in *M. crenulatus* and *M. Sowerbii*, nobis (Pl. VI. figs. 9, 12, 14). The radial plates are of the same great relative length in all the species, and the deltoids are proportionately reduced in size. The ambulacra vary in width and in their position within the sinuses. They are broadest in *M. elongatus* (Pl. VIII. fig. 1), next so in *M. Sowerbii* (Pl. VI. fig. 12) and *M. crenulatus*, and least so in the other two species (Pl. VIII. fig. 7). They are depressed below the edges of the sinuses in *M. elongatus*, but project above them in all the other forms. The median grooves of the lancet-plates are always exposed for a greater or less proportion of their length (Pl. IV. fig. 4; Pl. VI. fig. 10). The hydrospires are known to us in three species only, *M. angulatus*, *M. elongatus*, and

M. crenulatus. In the two former species there are three folds on each side of an ambulacrum, and in the latter there are certainly two and perhaps three.

The division of the spiracles by the deltoid ridge is much less evident in some species than in others. It is very complete in the *M. angulatus* and *M. Sowerbii*, shown in Pl. VI. figs. 7, 13; but less so in *M. crenulatus* (Pl. IV. fig. 1; Pl. VI. fig. 8), as the deltoid ridge does not extend down on to the peristomial portion of the plate; while it is almost entirely absent in two of the spiracles of *M. elongatus* seen in Pl. VIII. fig. 4.

Species. To *Mesoblastus* we refer the following species:—

Pentatrematites angulata, G. B. Sby. Carboniferous Limestone; Lancashire.
Pentatrematites crenulatus, Roemer. Carboniferous Limestone; Tournay, Belgium.
Mitra elongata, Cumberland (=*Pentatrematites oblonga*, G. B. Sby.). Carboniferous Limestone; Lancashire.
Mesoblastus giganteus, sp. nov. Carboniferous Limestone; Lancashire.
Mesoblastus Rofei, nobis. Carboniferous Limestone; Yorkshire and Lancashire.
Mesoblastus Sowerbii, nobis. Carboniferous Limestone; Lancashire.

We are strongly inclined to think that *Granatocrinus glaber*, M. & W., from the St. Louis group of Illinois, should also be referred to this genus; and the same is probably true of some other American species hitherto described under *Granatocrinus*.

Distribution. *Mesoblastus* is essentially a Carboniferous genus, and seems to occur on both sides of the Atlantic, though more abundant in Europe, where it partially replaces the American *Pentremites*.

Type. *Pentremites crenulatus*, Roemer.

Mesoblastus crenulatus, *Roemer*, sp.
(Pl. IV. figs. 1, 2; Pl. VI. figs. 8–10.)

Pentatrematites crenulatus, Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 366, t. 7. f. 15 *a–d*.
Pentremites crenulatus, de Koninck & Le Hon, Mém. Acad. Roy. Belgique, 1854, tome xxviii. Mém. 3, p. 199, t. 7. f. 4 *a–d*.
Pentremites crenulatus, Dujardin & Hupé, Hist. Nat. Zooph. Échinod. 1862, p. 96.

Sp. Char. Calyx globular, or ovoid, attenuated more towards the summit than the base; summit convex, peristome depressed; base truncate, slightly protuberant in the middle, or indistinctly trilobate; section pentagonal, with faintly concave sides; periphery at about one third the height from the base. Basal plates relatively large, and slightly protuberant; the pentagonal plate bears a median ridge, dividing the surface into two planes; the hexagonal ones each have two divergent ridges dividing their surface into three planes; around the articular facet each plate bears two (or perhaps more) little nodes. Radial plates long and moderately broad, transversely

arched and vertically curved; bodies small, concave in the middle line, bounded by ridges proceeding obliquely from the radial lips; limbs long, reaching to the summit, truncated above, with convex radio-deltoid sutures; sinuses very long, more or less visible in a basal view, with subparallel margins and thickened edges, the surfaces of the radial plates flattened or bevelled away immediately outside their edges; lips sharp and prominent, interradial sutures in slight concavities. Deltoid plates small, elongately triangular, more or less horizontal, and with somewhat constricted apices, which form a strongly crenulate (or punctate?) border to the peristome. Ambulacra projecting above the sides of the sinuses; lancet-plates exposed in the median line for about two thirds of their length; side plates oblong, thirty-five or more, with large sockets bounded by V-shaped margins; pores very small and inconspicuous. Hydrospire-folds two (and perhaps three) on each side of an ambulacrum. The four anterior spiracles more or less completely divided by a deltoid ridge of variable width; anal spiracle large, triangular-pyriform, with a reflected lip-like outer margin. Mouth generally rather large. Basal plates and bodies of the radials with strong equidistant granular ridges; the surface of the radials carries fine close granular lines crossing them obliquely from the sinuses in the direction of the interradial sutures, whilst the bevelled bands are ornamented with strong subimbricating chevron-like rugæ; the deltoid plates are granular.

Remarks. This species resembles *M. Sowerbii* (Pl. VI. figs. 12, 14) in having a protuberant base, but in other respects its general form is rather more like that of *M. angulatus* (Pl. VIII. figs. 7, 8), which, however, is a larger species, and has a concave base. The other European species of the genus are all much more elongate in outline (Pl. IV. fig. 3; Pl. VI. fig. 12; Pl. VIII. fig. 1), and have larger deltoid plates than *M. crenulatus*; while they also show no trace either of the subdivision of the base into separate planes, or of the very marked crenulation on the central ends of the deltoids, which are so characteristic of *M. crenulatus* (Pl. IV. fig. 1; Pl. VI. figs. 8, 9). In weathered specimens this crenulation takes the form of a border of small pits round the spiracles, as shown in Pl. VI. fig. 8. It is continued down the median groove of the ambulacrum, as is well seen in Pl. VI. fig. 10, and also in Roemer's figures[1], which, according to Hambach[2], "do not contradict" his statements as to the preservation of a "zigzag plicated integument which covers the ambulacral field." We do not think, however, that Hambach would have made these statements if he had seen specimens of this type instead of figures only. The results produced by the weathering of the ambulacra are well shown on Pl. IV. fig. 2. Fig. 1 represents an individual in which the spiracles are scarcely divided, owing to the smallness of the deltoid ridge. It is much larger in the original of Pl. VI. fig. 8, but does not quite reach the apex of the plate, as in the British species (figs. 7, 13).

Locality and Horizon. Tournay, Belgium: Upper Carboniferous Shale, Carboniferous Limestone.

[1] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. taf. iv. figs. 15 *c*, 15 *d*.

[2] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, p. 539

MESOBLASTUS ANGULATUS, *G. B. Sowerby*, sp.
(Pl. VI. fig. 7; Pl. VIII. figs. 7, 8; Pl. XVII. fig. 9.)

Pentatrematites angulata, G. B. Sby., Zool. Journ. 1828, vol. iv. no. 13, p. 89; *ibid.* 1834, vol. v. no. 20, pl. 33 Suppl., f. 1.
Pentremites angulatus, Phillips, Geol. York. pt. 2, 1836, p. 207, t. 3. f. 13.
Orbitremites ? angulatus, T. & T. Austin, Ann. & Mag. Nat. Hist. 1842, vol. x. p. 111.
Pentatrematites angulatus, Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 362.
Pentremites angulatus, Dujardin & Hupé, Hist. Nat. Zooph. Échinod. 1862, p. 94.
Granatocrinus angulatus, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 239.

Sp. Char. Calyx angularly globose, inflated along the lines of the ambulacra; summit more or less contracted; peristome concave; base contracted, but generally wider than the summit, concave, with a moderately deep columnar cavity, immediately surrounded by the apices of the ambulacra; section obtusely pentagonal, with the sides flattened above, but rather concave below; periphery almost equatorial. Basal plates small, limited to the columnar cavity. Radial plates large and exceedingly long, reaching the entire length of the calyx, lateral margins converging below, but rapidly expanding above, arched both laterally and longitudinally; bodies very small, confined to the columnar cavity, and inturned almost parallel to the vertical axis of the calyx; limbs very long, reaching from just beyond the margin of the basal cavity almost to the summit; sinuses very long and narrow, parallel-sided, with sharp edges; lips small, but prominent, and scarcely visible in a side view, owing to their inward flexure; interradial sutures in slight concavities. Deltoid plates small, elongately triangular, almost entirely confined to the summit, and hardly visible in a side view, either horizontal or inclined inwards. Ambulacra projecting above the margins of the radials, approaching one another closely at the base; lancet-plates narrow, hardly if at all exposed; side plates small, placed at a very high angle, forty or more; pores small and numerous, excavated in the edges of the radials. Hydrospire-folds three on each side of an ambulacrum; tubes long; sacs pyriform. Anterior spiracles almost horseshoe-shaped, within the area of the concave peristome, opening obliquely upwards and inwards; anal spiracle oval-pyriform, with the outer margin produced upwards and lip-like. Mouth small. Ornamentation minutely lineate granular.

Remarks. Mesoblastus angulatus may be readily distinguished by the inflated angular form of the calyx, the long curved ambulacra, small deltoids, and the peculiarly contracted summit and base. Seen in side view it somewhat resembles *Granatocrinus orbicularis* (Pl. IX. figs. 11, 12), but in other respects the two types are very different.

As in *M. elongatus* (Pl. VI. fig. 7; Pl. VIII. fig. 4), the deltoids are comparatively very small, but the elongated shape of the calyx, both in this species and in *M. Sowerbii* (Pl. VI. fig. 12; Pl. VIII. fig. 1), is quite unlike that of the present form.

The double character of the spiracles is unusually distinct in this species (Pl. VI. fig. 7); for the deltoid ridge, though not so wide as in some forms of *M. crenulatus*

(fig. 8), comes right down to the peristome, which is not always the case in that type (Pl. IV. fig. 1). It is equally complete, but less wide, in *M. Sowerbii* (Pl. VI. fig. 13).

M. angulatus appears to be a rare species, and we are acquainted with but few examples of it. The form of its hydrospires is well seen in Pl. XVII. fig. 9.

Locality and Horizon. Bolland District, Lancashire: Carboniferous Limestone.

MESOBLASTUS ELONGATUS, *Cumberland*, sp.

(Pl. VI. fig. 11; Pl. VIII. figs. 1–4; Pl. XI. fig. 15; Pl. XVII. fig. 10.)

Mitra elongata, Cumberland, Reliquiæ Conservatæ, 1826, p. 35, t. A. f. 1–3 (2nd row).
Pentatrematites oblonga, G. B. Sowerby, Zool. Journ. 1828, vol. iv. no. 13, p. 90; *ibid.* 1835, vol. v. pl. 33 Suppl., f. 3, & f. 4 (?).
Pentremites oblongus, Phillips, Geol. York. pt. 2, 1836, p. 207, t. 3. f. 11, & f. 12 (?).
Orbitremites? oblongus, T. & T. Austin, Ann. & Mag. Nat. Hist. 1842, vol. x. p. 111.
Pentatrematites oblongus, Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 362.
Pentremites oblongus, Dujardin & Hupé, Hist. Nat. Zooph. Échinod. 1862, p. 94.
Granatocrinus oblongus (pars), E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 239.

Sp. Char. Calyx long and barrel-shaped; summit truncate, flat, or a little concave; base widely excavated, but not deeply so; section pentagonal, with concave sides; periphery equatorial. Basal plates relatively large, slightly concave externally, with a large columnar facet. Radial plates very long, extending nearly the whole length of the calyx, with the lateral margins parallel; bodies small, rather concave, assisting to form the shallow basal concavity, bounded by obtuse, ill-defined ridges, which proceed obliquely from the radial lips; limbs long and narrow, sides sloping at a high angle, upper edges convex; sinus broad, relatively subpetaloid, margins sharp and prominent; lips small and projecting; the lines of the interradial sutures very straight, and in slight concavities. Deltoid plates small, elongately triangular. Ambulacra moderately broad, and of nearly uniform width throughout, rather flat, and sunk below the edges of the sinuses at their upper ends, but rising to a level with them at their apices; lancet-plate broad, the food-groove exposed for nearly its whole length, wide and open; side plates oblong, thirty-five or more in number, almost horizontal; outer side-plates very small. Hydrospire-folds three on each side of an ambulacrum; sacs large. Spiracles triangular-pyriform, usually with strong septa, opening nearly horizontally. Mouth moderately large. The ornament of the radial plates consists of a fine granular reticulation arising from the longitudinal rows of granules being crossed by transverse striæ, and more pronounced on the lower portions of the plates; on the radial limbs at the edges of the sinuses are a series of coarse, more or less transverse ridges, or elongated tubercles; deltoid plates coarsely granular.

Remarks. This is an elongated and exceedingly well-proportioned species, and anything but common[1]. The *Mitra elongata* of Cumberland appears to have been

[1] Besides the specimens in the National Collection, we have found one in the Museum of the Grammar School at Giggleswick, and another in the Free Public Museum at Blackburn.

completely overlooked by subsequent writers, but we have little doubt of its identity with *Pentatrematites oblonga*, G. B. Sowerby.

We regard Sowerby's fig. 4 as representing the typical form of *M. elongatus*. But it is much too rounded and globose in the upper part of the calyx. The enlarged figures of the ambulacra given by Sowerby do not altogether agree with one another. In that attached to fig. 4 the exposed lancet-plate is shown, but in the ambulacrum of fig. 3 the side plates are represented as meeting in the middle line. This is generally only the case near the end of the ambulacrum, which is of considerable relative width; but the lancet-plate is small in proportion, and the side plates rest on a wide hydrospire-plate, which is well shown in Pl. XI. fig. 15.

Mesoblastus elongatus is allied to only one species of the same genus, *M. Sowerbii*, but the ambulacra are wider than in that type (Pl. VI. fig. 12), whilst the calyx generally presents a more slender outline (Pl. VI. fig. 12; Pl. VIII. fig. 1); and when other characters of the respective species are examined, the differences appear much more marked. In *M. elongatus* the base is concave (Pl. VIII. fig. 3), in the other species protuberant (Pl. VI. figs. 12, 14). *M. elongatus*, from the length, as compared with the width of the calyx, may be said to represent the position held by *Granatocrinus Shumardi*, Meek and Worthen [1], in the genus *Granatocrinus*, if, indeed, it be a *Granatocrinus* and not a *Mesoblastus*.

The spiracles in the specimen which we have figured seem to vary considerably in the extent to which they are divided by the deltoid ridge (Pl. VIII. figs. 2–4).

Locality and Horizon. Whitewell and Bolland District, Lancashire; Settle, Yorkshire: Carboniferous Limestone.

Mesoblastus Sowerbii, sp. nov.

(Pl. VI. figs. 12–14; Pl. VIII. figs. 5, 6.)

Granatocrinus oblongus (pars), E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 239.

Sp. Char. Calyx elongate, angularly barrel-shaped, rather inflated along the ambulacra; summit truncated; peristome flat, or slightly concave; base truncated, but centrally protuberant, the protuberance extending below the level of the radial lips; section pentagonal, with strong projecting angles; periphery almost equatorial. Basal plates small, forming the central trilobate and protuberant portion of the base. Radial plates very long, more than two thirds the length of the calyx, very much arched, especially in a transverse direction; bodies small, concave; limbs very long, with parallel margins, the sides sloping at a high angle, obliquely and sharply truncated above; sinuses with subparallel sides and slightly thickened edges; lips small and projecting, but not extending quite as low as the protuberant base; concavely-bevelled bands adjoining, and parallel to the edges of the sinuses, are visible on the surface of the plates. Deltoid plates very acutely and unequally rhombic,

[1] Report Geol. Survey, Illinois, 1868, vol. iii. t. 18. f. 6 *b*.

concave in the middle line, their apices forming a portion of the truncated summit; anal deltoid only concave at its extreme (radial) end; radio-deltoid sutures sharply V-shaped. Ambulacra curved, and projecting above the edges of the sinuses; lancet-plates prominent, the steep sides projecting in a similar manner when the side-plates are removed; side-plates thirty-five to forty, inclined at a high angle. Hydrospires unknown. Anterior spiracles oval, in four pairs, divided by strong deltoid ridges; anal spiracle with an outer raised lip-like margin. Mouth indistinctly preserved, but apparently small. Ornament of radial plates not preserved, but probably lineate granular; deltoid plates with strong V-shaped striæ.

Remarks. We were formerly inclined to regard this form merely as a variety of *M. oblongus*, with an abnormally protuberant base. But on investigating the subject more minutely, it became apparent to us that this character, in conjunction with the more expanded outline of the calyx, and the more inflated and, to some extent, narrower ambulacra, demanded more than varietal separation.

Mr. G. B. Sowerby distinctly described the base of *M. elongatus* (as *Pentatrematites oblonga*) as being concave; he says, "The pelvis is small and concave." In the present form, though certainly not large, it is very distinctly protuberant (Pl. VI. fig. 12). The interradial areas of *M. Sowerbii* are much broader than in *M. elongatus* (Pl. VIII. fig. 1), and the ambulacra, which in the latter type are somewhat depressed below the edges of the sinuses, project a good deal beyond them in the present species. It is also probable, judging from the structure of *M. crenulatus*, that the protuberant base will become a feature of some importance and specific value in this group.

The mouth seems to be unusually large in our best specimen of *M. Sowerbii* (Pl. VI. fig. 13), but it has perhaps been artificially enlarged. The four anterior spiracles are pretty distinctly double, as the narrow deltoid ridge almost comes right down to the peristome.

A curious structure, which we cannot make out, is seen beneath the broken surface of the deltoid in the specimen shown on Pl. VIII. fig. 6. We thought at first that it represented the casts of the two converging hydrospire-canals, as in *Granatocrinus Norwoodi* (Pl. VII. figs. 7–9). But this is certainly not the case, for these canals in other specimens can be seen to reach the spiracles beneath the hydrospire-plates, which are well shown in this same individual.

We have much pleasure in naming this species after the late Mr. George Brettingham Sowerby, who was the earliest writer on British Blastoids, with the exception of Mr. G. Cumberland, of Bristol.

Locality and Horizon. Bolland District, Lancashire: Carboniferous Limestone.

Mesoblastus Rofei, sp. nov.

(Pl. IV. figs. 3, 4.)

Acentrotremites, sp., E. & C., Ann. & Mag. Nat. Hist. 1883, vol. xi. p. 233.

Sp. Char. Calyx roundly acorn-shaped, much arched along the ambulacra, and

resting naturally on their apices; summit more or less acuminate; greatest periphery nearly equatorial; section pentagonal, the sides above the equator almost flat, but below it rapidly becoming concave in the line of the interradial sutures; base concave and much contracted. Basal plates within the central depression, and completely concealed from sight in a side view of the calyx. Radial plates very long, much arched both longitudinally and transversely; bodies very small; limbs very long; radial sinuses narrow, decreasing in width but slowly, their margins thickened, with a narrow and rather concave band on the surface of the limbs, following their whole course. Deltoid plates very small (ill-preserved in all specimens examined). Ambulacra much arched, projecting above the margins of the sinuses; lancet-plate narrow and steep-sided, but with the median groove exposed; hydrospire-plate wide; pores exceedingly numerous, small, round, and close together. Hydrospire-folds two on each side of an ambulacrum. Spiracles small and close to the central aperture. Ornament consisting of longitudinal and transverse rows of striæ which give rise to a minute reticulation.

Remarks. The collection made by the late Mr. John Rofe, F.G.S., contained a mutilated specimen, which we formerly believed to be an *Acentrotremites*; but the temporary acquisition of additional material from the collection of Owens College, Manchester, through the courtesy of Prof. W. Boyd Dawkins, F.R.S., has convinced us that it should rather be referred to *Mesoblastus.* None of the specimens exhibit the summit in a good state of preservation, although there is quite sufficient evidence to show that the spiracles are formed after the type of *Mesoblastus* rather than that of *Acentrotremites* or of *Granatocrinus.*

The base of *M. Rofei* is concave, as in *M. elongatus* and *M. angulatus* (Pl. VIII. figs. 3, 8), and it is thus easily distinguished from *M. crenulatus* and *M. Sowerbii* (Pl. VI. figs. 9, 12, 14), in which the base is protuberant. *M. Rofei* is distinguished from *M. elongatus* (Pl. VIII. fig. 1) by the greater robustness of the calyx, flatter sides towards the summit, and about the equator, narrower ambulacra, and in all probability by possessing much smaller deltoid plates. As regards *M. angulatus*, the basal cavity is smaller than in the present species, the sectional diameter of the calyx much greater, and the form generally broader and shorter (Pl. VIII. figs. 7, 8). A partially decorticated specimen of *M. Rofei* exhibits two hydrospire-folds on each side of an ambulacrum, but we are not in a position to state whether this was the normal number or not. The external ornament closely resembles that of *Granatocrinus ellipticus* (Pl. VI. fig. 21; Pl. VIII. figs. 16, 19).

We have much pleasure in associating with this interesting species the name of the late Mr. J. Rofe, who was one of the first to realize the true morphological nature of many portions of the Blastoid economy.

The geological collection of Owens College, Manchester, contains another species of *Mesoblastus*, kindly lent to us by Prof. Boyd Dawkins, F.R.S., which we purpose shortly to describe elsewhere under the name of *M. giganteus*, from its relative size

as compared with the other species known to us. The base is protuberant as in *M. crenulatus* and *M. Sowerbii* (Pl. VI. figs. 9, 12, 14).

Localities and Horizon. Clitheroe, Lancashire: Carboniferous Limestone (presented by the late J. Rofe, Esq., F.G.S.). Yorkshire: Carboniferous Limestone (Coll. Owens College, Manchester).

Family *TROOSTOBLASTIDÆ*, E. & C., 1886.

Definition. Ambulacra very narrow, and descending sharply outwards from the much restricted peristome. Deltoids usually limited to the summit, and rarely visible externally. Lancet-plate entirely covered by the side-plates. Spiracles generally double, appearing as linear slits at the sides of the deltoid ridge, but not bounded distally by side plates.

Remarks. We have established this family to include the generic types which were first described as *Pentremites Reinwardti*, Troost, *P. lineatus*, Shumard, and *P. Woodmani*, Meek & Worthen, and are referred by us to *Troostocrinus*, *Metablastus*, and *Tricœlocrinus* respectively (Pl. III. figs. 14, 15; Pl. XII. fig. 11; and Pl. XIX. figs. 13–16). They differ from the Pentremitidæ in having a much contracted summit and very narrow ambulacra, owing to the lancet-plate being completely covered by the side plates, which do not bridge over the hydrospire-canals, or form the distal border of the spiracles. The radials are always very long, and the base is equally so in *Troostocrinus* and *Metablastus*, though not in *Tricœlocrinus* (Pl. XVI. fig. 18; Pl. XVIII. fig. 13). The length of the radial sinus varies a good deal, being shortest in *Troostocrinus Reinwardti* (Pl. XII. fig. 11), but, except in the anal interradius of this species (Fig. VII. on p. 193), the radial limbs extend right up to the summit and overlap the deltoids, so that they do not appear externally (Pl. III. figs. 14, 15; Pl. XII. fig. 11; Pl. XIX. figs. 13, 15).

The combination of all these characters marks off the Troostoblastidæ pretty distinctly from the other families of the class. The one which they approach most nearly is, of course, the Pentremitidæ, some forms both of *Pentremites* and of *Pentremitidea* having a very considerable resemblance to *Troostocrinus* and *Metablastus*, as will be pointed out subsequently; but a careful examination of sufficiently well-preserved material reveals important structural differences.

The geological history of the Troostoblastidæ is a curious one. *Troostocrinus Reinwardti* occurs in the Upper Silurian of America together with some other types which we cannot properly recognize, as they are only represented by internal casts or broken specimens. No Devonian species are known in America, although the family is represented in rocks of this age in England, France, and Spain; while the numerous Carboniferous species are all confined to America.

The following scheme shows the mutual relations of the three genera belonging to this family:—

A. Base long and tapering.

1. Posterior spiracles confluent with anus. The anal deltoid visible externally.	*Troostocrinus*, Shumard.
2. Posterior spiracles separate from anus. Deltoids all alike.	*Metablastus*, E. & C.

B. Base small, more or less truncated, and hollowed at the sides of the trihedral facet. Deltoids all alike. No anal spiracle.	*Tricœlocrinus*, Meek & Worthen.

Genus TROOSTOCRINUS, *F. B. Shumard*, 1865 (emend. *E. & C.*, 1886).

Pentatrematites Clavati, Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 372.
Troosticrinus, Shumard (pars), Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 384 (note).
Troostocrinus, Meek & Worthen (pars), Proc. Acad. Nat. Sci. Philad. 1868, p. 356.
Troostocrinus, Meek & Worthen (pars), Report Geol. Survey Illinois, 1873, vol. v. p. 507 (non White).
Troostocrinus, E. & C. (pars), Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 247.

Gen. Char. Calyx narrow, elongated, and somewhat fusiform; summit contracted, subtruncate, or slightly convex; base elongate and tapering, rounded above, but triangular below; section pentagonal; periphery nearly one third of the height from the summit. Basal plates about one third as high as the calyx. Radial plates long and narrow, the limbs much shorter than the bodies, and inclined to them at a very open angle; sinuses short, narrow, and almost parallel-sided. The four anterior deltoid plates overlapped by the radial limbs and confined to the summit; the posterior one larger, and appearing externally above the radial limbs as an unequally rhombic plate. Ambulacra short, and somewhat deeply set in the sinuses, especially at their proximal ends. Ten to twenty side plates, entirely concealing the lancet-plate. Five small spiracles, the four anterior ones more or less completely divided by the deltoid ridge, and the posterior one confluent with the anus. Hydrospires pendent, with three folds on each side.

History. This genus was proposed by Dr. F. B. Shumard [1], in his useful "Catalogue of North-American Palæozoic Fossils," pt. 1 [2], for subfusiform species of *Pentremites*, after the type of *P. Reinwardti*, Troost, possessing a slender outline, triangular base, and linear ambulacra. The genus was never described in detail, but was adopted provisionally in 1868 by Messrs. Meek and Worthen [3].

Dr. Shumard's remarks referred to above are as follows:—"There appear to me

[1] We write *Troostocrinus* on the principle of *plurimorum auctorum*; but the name was spelt *Troosticrinus* by Shumard.

[2] Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 384.

[3] Proc. Acad. Nat. Sci. Philadel. 1868, p. 356.

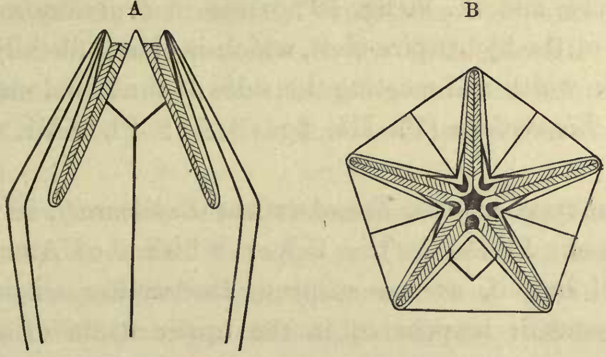
good reasons for removing this [*P. laterniformis*] and other subfusiform species as *Pentremites Reinwardtii*, *P. lineatus*, *P. bipyramidalis*, *P. Wortheni*, and perhaps *P. Grosvenori* from among the Pentremites, and grouping them together in a separate subsection under another name. These and allied forms are remarkable for their slender subfusiform shape, linear pseudambulacral fields, triangular base, and simple summit-structure. These external differences would seem to imply corresponding modifications in the internal economy of the animals of more than specific importance. If from a more thorough study of such species it should be deemed advisable to separate them from the genus *Pentremites*, I would propose the name *Troosticrinus* for the group." We have already expressed our concurrence in this proposition by adopting *Troostocrinus* in 1882 in the terms of Dr. Shumard's remarks; and we had prepared a definition of the genus which should embrace all the species named by Shumard (with the exception of *P. laterniformis*[1], which is only the internal cast of a *Pentremites*) and a few others as well. The morphological portion of the present work was written according to this view; and it was not until the section on the deltoid plates was passing through the press that we saw any reason to change it. But, as we have stated on pp. 36, 37, evidence was put before us by Mr. Wachsmuth which seemed to indicate that the Silurian species *Troostocrinus Reinwardti* should be separated generically from its successors of Carboniferous age on account of the anal deltoid being larger than its fellows, and appearing externally above the radial limbs (see Fig. VII. on p. 193). But we hesitated to take this course at first, though we have now decided to do so for two reasons—(1) Mr. Wachsmuth has been good enough to examine for us all his available material of this species, and he finds that the anal deltoid appears externally in all the specimens which are sufficiently well preserved to show the structure of the summit. (2) *Troostocrinus Reinwardti* has an anal spiracle; but in Shumard's *Pentremites lineatus* (Pl. III. figs. 14, 15), and in most of the other Carboniferous species, the anus opens separately from the two posterior spiracles as in *Tricœlocrinus* (Pl. XVIII. fig. 15; Pl. XIX. figs. 15, 16).

The combination of these two characters appears to us to be sufficient to warrant the generic separation of *Pentremites Reinwardti* and *P. lineatus*. The former, having been originally described by Troost, was the first comprehensible type named by Shumard in the group of species which he proposed to refer to *Troostocrinus*[1]. There is therefore every reason for making it the type species of the genus as we now define it; while in accordance with a suggestion from Mr. Wachsmuth, we propose to establish a new genus, which we have called *Metablastus*, for *Pentremites lineatus*

[1] If *P. laterniformis* is really only an internal cast of a *Pentremites*, it might be argued that *Troostocrinus* is only a synonym of that genus, because *P. laterniformis* was the first named among the species referred by Shumard to *Troostocrinus*. We have preferred, however, to regard the next species named by him as the type of the genus (*P. Reinwardti*), and we believe that most palæontologists will think that we have taken the right course under the circumstances.

and its allies from the Carboniferous strata. One of these later forms, however, *P. Grosvenori*, Shumard, should perhaps be referred to *Troostocrinus* as we define it; for it has five undivided spiracles, one of which is confluent with the anus, as is well seen in Shumard's figure of the summit. He described the deltoids of this type as "small, lozenge-shaped, and rather prominent in the middle;" and in the side view which he figures one deltoid answering to this description does appear externally [1]. It may also be traced, though not clearly so, in the figure of the summit; but the interradial sutures in the other four interradii appear to come right up to the spiracles. If this be really the case, *Pentremites Grosvenori* is an undoubted *Troostocrinus*, and the genus will then range up into the Carboniferous period. It seems to be a rare species, and the question of its generic position can only be solved by our American colleagues. We have no information respecting any other specimens than the one described by Shumard in 1858.

Fig. VII.



Diagrams of *Troostocrinus Reinwardti*. A. The anal side. B. Summit view. The radio-deltoid sutures are shown by rather darker lines.

Remarks. The genus *Troostocrinus*, as limited by us, is one of peculiar interest. For it is the only Silurian genus of Blastoidea which is at all satisfactorily known, and it presents a curious departure from the ordinary structure of the regular Blastoids in having the deltoid of the anal side so much larger than its fellows as to appear on the exterior of the calyx above the radial limbs (Fig. VII.). The only other exceptional structure of this kind which we know of in the regular Blastoids is the division of the posterior deltoid of *Elæacrinus* into two parts by an anal plate (Pl. XVIII. fig. 19). This is foreshadowed, as it were, in the superficial division of the other deltoids both in this genus and also in *Schizoblastus Sayi*, as we have pointed out on p. 35; and in like manner the anal deltoid of a specimen of *Pentremitidea Paillettei* was noticed by Roemer [2] to be larger than its fellows, which are just visible externally, though this is not the case in *Troostocrinus*, as the limbs of the radials completely overlap the four anterior deltoids so that only their inner faces are exposed (Fig. VII.).

[1] Trans. St. Louis Acad. Sci. 1858, vol. i. no. 2, p. 241, pl. 9. figs. 2 *a*, 2 *b*.

[2] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 369, Taf. iv. fig. 17 *b*.

As a general rule, the sharp median ridges of these deltoid plates almost completely separate the proximal ends of the narrow radial sinuses at their sides, which remain open as the linear spiracles; but in *T. Grosvenori* this does not appear to be the case, and there are only five spiracular openings. This species thus differs from *T. Reinwardti* in the same way as our two specimens of *Pentremites elongatus* figured on Pl. I. figs. 4, 5, differ from one another; while in *Pentremitidea angulata* (Pl. IV. fig. 14) two of the spiracles are completely divided, and a third not. It is to this latter genus that *Troostocrinus* seems most closely allied. Each has a long basal cup, narrow ambulacra, and an undivided anal spiracle; while both species of *Troostocrinus* approach *P. Paillettei* and *P. Lusitanica* in outline (Pl. IV. figs. 9, 11; Pl. V. fig. 20; Pl. XII. fig. 11; Pl. XIV. fig. 13). These two, however, are rather extreme forms of the genus, which is very closely linked with *Pentremites*, especially in the structure of the spiracles. The side plates project beyond the lancet-plate so as to bridge over the hydrospire-cleft, and convert it into a canal, as seen in Pl. IV. fig. 14, and Pl. V. fig. 19; while in *Troostocrinus* the spiracle is the open proximal end of the hydrospire-cleft, which is closed distally by the ambulacrum slightly increasing in width and meeting the sides of the radial sinus as in *Metablastus*, *Schizoblastus*, and *Elæacrinus* (Pl. III. figs. 3, 14; Pl. XVI. fig. 12; Pl. XVIII. fig. 16).

Distribution. The type species, *Troostocrinus Reinwardti*, is characteristic of the Niagara (or Wenlock) Period in the Upper Silurian of America. No Devonian species are known, but if, as we suspect, *Pentremites Grosvenori*, Shumard, be referable to this genus, it reappeared in the upper strata of the American Carboniferous Limestone.

Type. Pentremites Reinwardtii, Troost.

Troostocrinus Reinwardti, *Troost*, sp.

(Fig. VII.; Pl. XII. figs. 11, 12; Pl. XVII. fig. 17.)

Pentremites Reinwardtii, Troost, Trans. Geol. Soc. Pennsylv. 1835, vol. i. p. 224, t. 10. ff. 10, 11.
Pentremites Reinwardtii, Troost, Fifth & Sixth Geol. Reports, State of Tennessee, 1840 and 1841, pp. 58 & 14.
Pentremites Reinwardti, Yandell & Shumard, Contrib. Geol. Kentucky, 1847, p. 6.
Pentremites Reinwardti, Roemer, Neues Jahrb. f. Mineral. 1848, p. 296.
Pentremites Reinwardtii, Yandell, Proc. American Assoc. Adv. Sci. for 1851 [1851], p. 232.
Pentatrematites Reinwardtii, Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 372, t. 6. f. 12 *a–c*.
Pentatrematites Reinwardtii, Roemer, Sil. Fauna W. Tennessee, 1860, p. 60, t. 3. f. 2 *a–c*.
Pentatremites Reinwardti, Bronn, Klassen und Ordn. Thier-Reichs, 1860, Bd. ii. t. 23. f. 4 A, B.
Pentremites Reinwardtii, Dujardin & Hupé, Hist. Nat. Zooph. Échinod. 1862, p. 99.
Troosticrinus Reinwardtii, Shumard, Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, pp. 384, 385 (note).
Troostocrinus Reinwardtii, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 249.

Sp. Char. Calyx elongately fusiform; summit subtruncate, and much contracted, the rapid attenuation of the calyx above the periphery giving to it an almost pointed appearance; base long and slender; interbasal sutures straight, and not well defined; section pentagonal, the sides straight above the radial lips, but below them somewhat concave; periphery rather more than one fourth the total length of the calyx from the summit. Basal plates forming a slender cup, rounded above, but triangular below, with flat sides, and slightly constricted at its lower end. Radial plates very narrow and long; bodies one and a quarter times as long as the limbs, and subangular in the middle line; limbs with flat sides; interradial sutures lodged in very faint depressions; sinuses short, very narrow, almost parallel-sided, with sharp margins; lips simple, not produced. Normal deltoid plates invisible externally, and little more than sharp crests beneath the radial limbs; the azygos one unequally rhombic, with its crest truncated by the anus. Ambulacra short and narrow, rather below the edges of the sinuses; side plates and outer side plates alternately triangular, from twelve to thirty in number, and entirely concealing the lancet-plates. Spiracles almost completely divided into linear slits by the deltoid crests; the posterior one confluent with the anus. Three hydrospire-folds on each side of an ambulacrum. Column unknown. Ornament of closely set, microscopically fine lines parallel to the margins of the plates.

Remarks. This species is readily distinguished from the only other one which we can refer to *Troostocrinus* by its divided spiracles and by the sharp angle in the calyx at the level of the radial lips. *Troostocrinus*? *Grosvenori*, as figured by Shumard [1], has wider ambulacra, undivided spiracles, and a calyx which tapers regularly, but slowly, downwards from a line considerably above that of the radial lips.

Metablastus lineatus resembles *T. Reinwardti* in the doubly conical shape of the calyx, but the ambulacra are relatively much longer, and there are ten spiracles in addition to the anal opening (Pl. III. figs. 14, 15). There are various other more or less fusiform species of so-called *Pentremites* which may, perhaps, have to be referred to *Troostocrinus* when the characters of their summit are properly known. Such, for example, are *P. bipyramidalis*, Hall, and *P. Wortheni*, Hall, both from the Keokuk Group of America, and *P. Varsouviensis*, Worthen, from the Warsaw Limestone of Illinois; but we are inclined to think, as we shall explain subsequently, that they belong to *Metablastus*. The *Troostocrinus Wachsmuthi* of Gurley [2] certainly belongs to this genus, as the anus is distinct from the spiracles at its sides. But we are in some doubt about the type from the Lower Devonian of Spain, which we formerly described as *Troostocrinus Hispanicus* [3] (Pl. V. fig. 21), as its summit is not sufficiently well preserved to show the generic characters properly. But it is a

[1] Trans. St. Louis Acad. Sci. 1858, vol. i. no. 2, pl. 9. fig. 2 *d*.

[2] 'New Carboniferous Fossils.' Bulletin no. 2, Feb. 25, 1884, p. 1.

[3] Ann. & Mag. Nat. Hist. 1883, vol. xi. p. 245.

much more robust species than *T. Reinwardti*, having larger, wider, and more expanding ambulacra, with a more truncated and therefore more spacious summit.

Locality and Horizon. Deccatur County, Tennessee: Niagara Group (=Wenlock Series), Upper Silurian.

Genus METABLASTUS, *gen. nov.*

Troosticrinus, Shumard (pars), Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 384 (note).
Troostocrinus, Meek & Worthen (pars), Proc. Acad. Nat. Sci. Philad. 1868, p. 356.
Troostocrinus, Meek & Worthen (pars), Report Geol. Survey Illinois, 1873, vol. v. p. 507.
Belemnocrinus ?, Munier-Chalmas (MS.), Journ. Conchyliol. 1876, tome xvi. p. 105 (non White).
Belocrinus ?, Munier-Chalmas (MS.), Bull. Soc. Géol. France, 1881, tome ix. p. 503.
Troostocrinus, E. & C. (pars), Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 247.

Gen. Char. Calyx narrow, slender, fusiform, or subfusiform; summit usually acuminate, always contracted, and sometimes subtruncate or a little convex; base elongate, sometimes tapering rapidly, sometimes truncate, triangular or triangular-pyramidal, flattened below on all three sides; section pentagonal above, triangular below; periphery nearly halfway from the summit. Radial plates long and narrow, the limbs much shorter than the bodies; sinuses narrow and deep. Deltoid plates small and inconspicuous, confined to the immediate neighbourhood of the summit. Ambulacra short, narrow, and usually sublinear, deeply set in the sinuses; side plates, eighteen to sixty in number, quite concealing the lancet-plate. Spiracles ten linear slits between the ambulacra and the deltoid ridges; the posterior pair separate from the anus and nearer the peristome than it. Four hydrospire-folds on each side of an ambulacrum.

History. We have been led to separate this genus from *Troostocrinus* partly in consequence of Mr. Wachsmuth's discovery (which he generously communicated to us) that the anal deltoid of *T. Reinwardti* is different from its fellows, and appears externally; and partly because we were struck by the fact that there is an anal spiracle in this species as in *T. Grosvenori*, but not in any of the others which have been hitherto referred to *Troostocrinus* (Pl. III. figs. 14, 15; Pl. XVIII. fig. 15). All of these agree in having the two posterior spiracles separate from the anus and opening nearer the peristome than it, just as in *Tricœlocrinus* (Pl. XIX. figs. 15, 16). The combination of this character, with the presence of five similar deltoids and a trihedral basal cup, appears to us to be of generic value. We were at first unwilling to act on Mr. Wachsmuth's discovery and limit the genus *Troostocrinus* to *T. Reinwardti*, with the possible addition of *T. Grosvenori*, as we hoped that he might have been able to discuss the question himself. But as he felt unable to take it up, in consequence of his other engagements, he generously waived his own claims to priority and left us free to act, as we have already explained on p. 112. With his concurrence, therefore, we now propose the genus *Metablastus* with the characters given above.

Remarks. We have already seen that *Troostocrinus* approaches the *Pentremitidæ* through *Pentremitidea Paillettei*. *Metablastus* and *Tricœlocrinus* on the other hand have much resemblance in the general structure of their spiracles, both to the Nucleoblastidæ, and to some forms of *Orophocrinus*, as we have explained on p. 110. But they altogether differ both from these Blastoids and from one another in the form of the calyx. In this respect *Metablastus* resembles *Troostocrinus*, the basals and radials of both genera being very much elongated and the ambulacra very narrow (Pl. V. figs. 21, 22; Pl. XII. fig. 11). We have no specimens of *Troostocrinus Reinwardti* which are perfect enough to show the constriction at the lower end of the basal cup which is figured by Roemer. But there is nothing like it in any species of *Metablastus* that we have seen, even in *M. lineatus*, in which the base is less markedly trihedral than in forms like *M. Wachsmuthi* and others. The five sides of the radial portion of the cup pass gradually downwards into the three sides of its basal portion in the manner described on pp. 16–18 [1]. The two strong ridges which start from the lips of radials A and B approach one another below and unite into a single median ridge on the azygos basal. This forms one edge of the trihedral base, while the other two are the strong ridges on radials C and E, that on radius D, which is the weakest of all, gradually dividing and dying away below. This structure is shown very well in the basal cup of the specimen of which the summit is seen in Pl. XVIII. fig. 15, and we believe it to be eminently characteristic of *Metablastus*. It can be traced in *M. lineatus*, which rather resembles *Troostocrinus Reinwardti* in the elongate and tapering form of the basal cup, while the three ridges are extremely prominent in the shorter and more flattened base of *Tricœlocrinus* (Pl. XVI. figs. 17, 18; Pl. XIX. figs. 13, 14). They are also very well marked in the long basal cup which has been noticed by Munier-Chalmas and by Oehlert under the name *Belocrinus Cottaldi*, and it is chiefly for this reason that we formerly referred it to a species of *Troostocrinus* (Pl. V. fig. 22), which name must now be changed into *Metablastus*, though it is of course possible that an entire calyx may eventually be discovered with different summit-characters from those of this genus.

The morphology of the spiracles of *Metablastus*, and their relations to those of *Orophocrinus* and *Schizoblastus*, has been described on pp. 109–111. In the type species, both of the latter genus and of *Metablastus*, the lancet-plate is triply perforate (Pl. XVII. figs. 1, 18), though we do not know how far this is the case in other species. The same may be said of the hydrospires of *Metablastus*, which are quadruple in *M. lineatus* (Pl. XVII. fig. 18); but we have no sections of them in any other species.

The ambulacral pinnules are known in three species of *Metablastus*, having been described by White in *M. lineatus*, and figured in *M. Varsouviensis* by Meek and Worthen, while they are also preserved in one of Wachsmuth's specimens of *M. Wortheni* (Pl. III. fig. 13). There are some suspicious-looking lines on the

[1] The name *Metablastus* should now be substituted for *Troostocrinus* in this description.

radial limbs of this individual, which might be taken as indicating the presence of the deltoids externally; but we think that they are only clefts in the calcite, and not radio-deltoid sutures.

Distribution. If we are correct in referring to *Metablastus* the imperfect specimens from the Niagara Group which have been described by Hall as *Pentremites subcylindrica* and *Codaster pentalobus* respectively, then the genus dates back to Silurian times. Failing these, the oldest representatives of the genus would be *M. Cottaldi*, Mun.-Chalm., sp., from the Lower Devonian (Taunusien) of France, and *M. Hispanicus*, E. & C., from a slightly higher horizon (Eifelien) in Spain. There is a doubtful species in the Plymouth Limestone (Middle Devonian) of Britain; but the majority of the forms are from the American Carboniferous system. The type species, *M. lineatus*, occurs in the Upper Burlington Limestone, two are found in the Keokuk Group, and two more in the Warsaw Limestone, though none are known in the Kaskaskia Limestone, which contains *Pentremites* in such abundance.

Species. The following list contains the names of the species which we refer to *Metablastus*, together with one or two other doubtful types which appear to us to be undoubted members of the Troostoblastidæ, though their generic position is uncertain:—

Belocrinus Cottaldi, Munier-Chalmas (MS.). Grès de Gahard, Lower Devonian; France.

Troostocrinus Hispanicus, E. & C. Calcaire d'Arnao, Lower Devonian; Spain.

Pentremites lineatus, Shumard. Upper Burlington Limestone, Subcarboniferous; Illinois and Iowa.

Pentremites Varsouviensis, Worthen. Warsaw Limestone, Subcarboniferous; Illinois.

Troostocrinus Wachsmuthi, Gurley. Warsaw Limestone, Subcarboniferous; Indiana.

Pentremites Wortheni, Hall. Keokuk Limestone, Subcarboniferous; Iowa, Illinois, Indiana.

Doubtful Species.

Pentremites subcylindrica, Hall & Whitfield. Niagara Group, Upper Silurian; Ohio.

Codaster pentalobus, Hall. Niagara Group, Upper Silurian; Indiana.

The above list includes nearly all the species which we formerly referred to *Troostocrinus*, of course with the exception of *T. Reinwardti* and *T. Grosvenori*, to which we now limit this name. But we now omit the *Pentremites subtruncatus* of Hall, which we formerly took to be a *Troostocrinus*, on account of his describing it as belonging to the same type of form as *P. Reinwardti*, and we suspect that it will turn out to be a *Codaster*. We also omit the *Pentremites clavatus* of Hambach,

which we were formerly inclined to refer to *Troostocrinus* on account of its extremely elongate form and narrow summit. But we have since seen specimens either of this species or of *P. gemmiformis*, Hambach (if, indeed, they are not identical), and we find that it is a true *Pentremites*, which passes on the one hand into *Pentremitidea* and the Troostoblastidæ, and on the other into such forms of *P. pyriformis* as are represented on Pl. II. figs. 28, 30. Hambach has already pointed this out, and we are glad to be able to agree with him.

Type. Pentremites lineatus, Shumard.

METABLASTUS LINEATUS, *F. B. Shumard*, sp.

(Pl. III. figs. 14, 15; Pl. XVII. fig. 18.)

Pentremites lineatus, Shumard, Trans. St. Louis Acad. Sci. 1858, vol. i. no. 2, pp. 241, 247, t. 9. f. 3, *a, b*.

Troosticrinus (*Pentremites*) *lineatus,* Shumard, *ibid.*, 1865, vol. ii. no. 2, p. 384 (and note).

Pentremites lineatus, White, Boston Journ. Nat. Hist. 1863, vol. vii. no. 4, p. 488.

Troostocrinus lineatus, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 249.

Sp. Char. Calyx elongately subfusiform; summit very much contracted, and truncated obliquely outwards; base roundly pentagonal above, rapidly tapering downwards to a narrow trihedral extremity; section above the lips distinctly pentagonal; periphery one third from the summit. Basal plates elongate, slender, rounded above but subangular below; interbasal sutures on the flat sides. Radial plates very long and narrow, increasing but little in width, bodies and limbs as nearly as possible of equal width; bodies arched and angular in the middle line, sides flattened, limbs lanceolate; lips not produced; sinuses very narrow and deeply cleft; interradial sutures in very slight concavities. Deltoid plates appearing round the summit as strong crests overlapped by the radial limbs; radio-deltoid sutures almost vertical on the sides of the sinuses. Ambulacra very narrow, linear, and one third the length of the calyx, deeply set in the sinuses; side plates fifty; lancet-plate with three canals arranged in a triangle. Hydrospire-folds four on each side of an ambulacrum; sacs pyriform; spiracles linear. Mouth small, very much contracted. Anus a large oval opening in the posterior deltoid with somewhat thickened edges. Column circular. Ornament of microscopic lines arranged parallel to the margins of the plates.

Remarks. Shumard [1] has given a good description of this species, so far as it could be made out from a somewhat crushed specimen, but the structure of the summit has hitherto been entirely unknown. There is, however, a good though slightly crushed example of it in Mr. Wachsmuth's collection, which shows the ten linear spiracles and the unusually large anal opening (Pl. III. figs. 14, 15). Neither of these views, however, is adapted for showing the radio-deltoid sutures, which have an altogether different position from that assigned to them by Shumard. They are shown in his figure as appearing on the exterior of the calyx above the truncated ends of the radial

[1] Trans. St. Louis Acad. Sci. 1858, vol. i. no. 2, p. 241, pl. ix. fig. 3.

limbs, just as in Roemer's first figure of *Pentremites Reinwardti.* But, like the four normal deltoids of that species and those of *Pentremitidea*, *Cryptoschisma*, *Codaster*, *Phænoschisma*, *Tricœlocrinus*, and, we may also add, of *Stephanocrinus* (Pl. V. figs. 1, 3, 17, 24; Pl. XI. figs. 5, 6; Pl. XII. figs. 2, 5, 6; Pl. XIX. figs. 12, 13), they are overlapped externally by the radial limbs. This is well shown in our figure of *Troostocrinus Reinwardti* on p. 193; and it is very evident in some of Mr. Wachsmuth's smaller specimens. The position of the radio-deltoid sutures upon the high walls of the radial sinuses is almost a vertical one, *i. e.* parallel to the long axis of the calyx; and they consequently meet the ambulacra at rather a sharp angle and not almost transversely, as in *Tricœlocrinus* (Pl. XIX. figs. 13, 15), or in *Codaster* and *Cryptoschisma* (Pl. V. fig. 24; Pl. XII. figs. 1–6). *Phænoschisma acutum* resembles *Codaster* (Pl. XIV. figs 11, 12); but *P. nobile* and *P. Verneuili* are more like *Metablastus lineatus* in the position of the radio-deltoid sutures (Pl. XI. figs. 1–3, 5, 6).

Although cut off from the exterior of the calyx by the overlap of the radial limbs, the deltoids of this species are very conspicuous objects in the summit; for they form high ridges between the linear spiracles (Pl. III. fig. 14), which almost reach the edge of the extremely contracted peristome, and are very plainly visible in an interradial view of the calyx. They are of greater relative height in this species than in any other form of *Metablastus* that we have seen. It seems to be not unlike *M. Wortheni*, Hall, sp., as was suggested by Shumard; but, as far as we can make out from Hall's figure and from the two crushed specimens of his type which we have seen, the Keokuk species has relatively longer ambulacra and a considerably stouter basal cup than *M. lineatus.* We know too little of the other Keokuk species described by Hall (*M. bipyramidalis*) to be able to compare it with the Burlington form; but the latter differs considerably from the two specimens of *Metablastus* which occur in the Warsaw Limestone, viz. *M. Varsouviensis*, Meek and Worthen, sp., and *M. Wachsmuthi*, Gurley, sp. We think that we have identified both of them in Mr. Wachsmuth's collection, and in each case the base is shorter, less tapering, and much more distinctly trihedral than in *M. lineatus.* In fact, they are the connecting links between this genus and *Tricœlocrinus*, but they do not present the three hollows on the interbasal sutures which form the essential characteristic of this genus (Pl. XVI. figs. 17, 18; Pl. XIX. figs. 13, 14).

Locality and Horizon. Burlington, Iowa: Upper Burlington Limestone, Subcarboniferous.

Metablastus Hispanicus, *E. & C.*

(Pl. V. fig. 21.)

Troostocrinus Hispanicus, E. & C., Ann. & Mag. Nat. Hist. 1883, vol. xi. p. 245.

Sp. Char. Calyx elongated, robustly subfusiform; summit rounded, but the characters not well preserved; basal cup conical, its sides being compressed and flattened below, so as to give it a triangular form; section pentagonal, with concave

sides. Basal plates robust, gently convex, forming a strong obtusely conical cup; interbasal sutures not in concavities. Radial plates long and narrow, parallel-sided, twice the length of the basals, and each about equally divided into body and limbs; interradial sutures comparatively straight, placed in depressions; sinuses narrow and sublinear; lips slightly projecting. Ambulacra slanting sharply down from the summit, and gradually decreasing in width; side plates at least twenty-five in number on each side, projecting above the margins of the sinuses. Deltoid plates exceedingly minute, and quite apical. Hydrospires, spiracles, column, and ornament unknown.

Remarks. The elongated form of the calyx in this species seems to us to leave little room for doubt that it is one of the Troostoblastidæ; and we have referred it to *Metablastus* rather than to *Troostocrinus*, under which name we originally described it on account of its tendency towards a trihedral base. At the same time we are quite prepared to admit that, when its summit characters are fully known, it may turn out to be nothing more than a much elongated form of *Pentremitidea*, standing in the same relation to some varieties of *P. clavata* (Pl. V. fig. 17) as *Pentremites clavatus*, Hambach, bears to *P. pyriformis*, Say. It is a much more robust species than *Troostocrinus Reinwardti*, having larger, wider, and more expanding ambulacra than are characteristic of that form (Pl. XII. fig. 11). The summit is also more spacious and more truncated than the corresponding part of *T. Reinwardti*. The Spanish fossil may be distinguished from *M. bipyramidalis*, Hall, sp., by its shorter ambulacra and fewer side plates, together with the greater elongation of the calyx from the radial lips downwards. The proportions of *T. Grosvenori*, Shumard, are also quite different from those of *M. Hispanicus*. Perhaps, on the whole, the latter agrees better with *M. Wortheni*, Hall, sp., than with any of the species just named, except that its ambulacra are broader. They are relatively longer than those of *Pentremites subcylindrica*, Hall & Whit., and the radial angles are very different in the two forms, while the long radials of *M. lineatus*, Shum., sp., are sufficient to distinguish it from *M. Hispanicus*. In the form of the radial plates, the relatively broad ambulacra, and the cone-like base, the latter exhibits a resemblance to *Pentremites clavatus*, Hambach; but we much doubt whether the summit structure be the same in the two species.

Locality and Horizon. Colle, near Sabero, Province of Leon, Spain: Calcaire d'Arnao, Lower Devonian. (Presented by Dr. P. H. Carpenter, F.R.S.)

METABLASTUS COTTALDI, *Mun.-Chalmas*, sp.

(Pl. V. fig. 22.)

Belemnocrinus Cottaldi, Mun.-Chalmas (MS.), Journ. Conchyl. 1876, tome xvi. p. 105.

Belocrinus Cottaldi, Mun.-Chalmas (MS.), Bull. Soc. Géol. France, 1881, tome ix. no. 6, p. 503.

Belocrinus Cottaldi, Œhlert, *ibid.* 1882, tome x. p. 362, t. 9. f. 3, *a–e*.

Sp. Char. Basal plates forming a large and long cup, subangular or angularly rounded in section; the sides at the upper end are more or less flattened, whilst below they are grooved along the lines of suture, and the bodies of the plates are more sharply angular. The upper ends of the two large plates have median re-entering angles, whilst the third or small basal is pointed above; the lower end of the cup is triangular, and the columnar facet small and round. When separated the plates are found to have a considerable thickness, the lower part of the cup becoming solid, except for the continuation of the columnar canal.

Remarks. We have already called attention to the probable Blastoid nature of this peculiar fossil [1], and now, through the kindness of M. Munier-Chalmas, have had an opportunity of examining some examples of it, one of which (natural size) is shown on Pl. V. fig. 22.

There can, we think, be little doubt that it is the base of what must have been a large species of *Metablastus.* The lower part of it is distinctly trihedral, and the upper part roundly pentagonal, the one condition passing into the other in the manner described on pp. 16–18. All the ridges which are characteristic of the basal plates of a Blastoid can be distinctly traced upon the specimen which we have figured (Pl. V. fig. 22). The large plate which is seen in the figure is the basal, *y* [2], and its median ridge is No. 4, the one corresponding to radius C; while the grooves at its sides mark the lines of the interbasal sutures.

This remarkable fossil was discovered by M. Munier-Chalmas, and was described by him under the name of *Belemnocrinus Cottaldi* in the following terms [3]:—"Le calice, qui est conique, se compose de 5 pièces longitudinales. Il présente, vers sa base, 3 sillons externes, et, à sa partie supérieure, une cavité pentagonale très profonde." As, however, it was subsequently discovered that the name *Belemnocrinus* had been preoccupied by White, it was changed into *Belocrinus* in 1881 [4]. We pointed out in 1883 [5] that the fossil appeared to us to be nothing but the elongated basal cup of a *Troostocrinus* or *Pentremitidea*; and, after examining specimens of it for ourselves, we decided to refer it to *Troostocrinus.* But when it became necessary to limit the meaning of this name in the sense explained above, and to refer *Belocrinus Cottaldi*, together with most of the species of *Troostocrinus*, to a new genus, we did not feel ourselves called upon to adopt M. Munier-Chalmas' generic name. For we have no knowledge of the summit characters of the species, and his description of it as having five basals is certainly incorrect. We should say, however, that

[1] Ann. & Mag. Nat. Hist. 1883, vol. ix. p. 245.

[2] See the diagrams on pp. 13, 17.

[3] Journ. Conchyl. 1876, tom. xvi. p. 10

[4] Bull. Soc. Géol. de France, 1881, tome ix. p. 503.

[5] Ann. & Mag. Nat. Hist. 1883, vol. xi. p. 245.

only three are represented in the diagram given by Œhlert[1], which is as correct as we could wish. But it is scarcely possible to define a new genus of Blastoids by the single character of a tripartite base which is common to the whole class; and though we refer the type to *Metablastus* for the present, it may prove to be a different genus when its summit characters are known.

Locality and Horizon. Bois-Roux, Commune de Gahard, Ille-et-Vilaine, France: Grès de Gahard, Lower Devonian. (Presented by Dr. P. H. Carpenter, F.R.S.)

Genus TRICŒLOCRINUS, *Meek & Worthen*, 1868.

Tricœlocrinus, M. & W., Proc. Acad. Nat. Sci. Philad. 1868, p. 356.
Tricœlocrinus, M. & W., Report Geol. Survey Illinois, 1873, vol. v. p. 506.
Tricœlocrinus, E. & C., Ann. & Mag. Nat. Hist. 1883, vol. xi. p. 242.

Gen. Char. Calyx pyramidal, or pyramidal subovate, broadest below and narrowing upwards; summit always small, and much contracted; base short and moderately wide, trihedral at its lower end, and excavated more or less deeply along the inter-basal sutures, the excavations extending for a greater or less length on to the surfaces of three of the radials. Basal plates carinate and more or less hollowed laterally. Radial plates thick, always long and narrow, and more or less carinate in the middle line below the radial lips, three of them being partially excavated below the carinæ; sinuses narrow and deep, but not penetrating through the thickness of the radials except near the summit. Deltoid plates small and probably confined to the summit within the radial limbs. Ambulacra usually long, remarkably narrow, or linear, and deeply situated in the sinuses; side and outer side plates minute. Hydrospires small, not pendent, but enclosed within the substance of the radial plates for the greater part of their length. Anterior spiracles small, more or less completely divided, and situated close round the mouth; the two posterior spiracles separate both from one another and from the anus. Mouth small. Anus large. Column circular.

History. The name *Tricœlocrinus* was suggested by Messrs. Meek and Worthen in 1868 as a proposed subgenus of *Troostocrinus*, Shumard, for a type in which "the body is broadest below, while the base is comparatively very short and wide, and has the three spaces corresponding to the flattened sides of the typical species of *Troostocrinus* so very profoundly and broadly excavated as to impart a very remarkable appearance to the lower part of the fossil."

In 1883 we adopted *Tricœlocrinus* as a genus, and gave some further details of its structure, more especially with reference to the hydrospires.

Remarks. The figures of *Tricœlocrinus Woodmani*[2], the type of the genus (Pl. XIX.

[1] Bull. Soc. Géol. de France, 1882, tome x. p. 362.
[2] Report Geol. Survey Illinois, 1873, vol. v. pl. xvi. fig. 4.

figs. 13–16), represent a form which is so very different from *Troostocrinus* or *Metablastus* that we had no hesitation in accepting *Tricœlocrinus* as a valid genus.

The characters of the type, as given by Messrs. Meek and Worthen [1], are so generally applicable to the whole group of species that we here reproduce them. The strongly pentagonal form of the calyx, as seen both from above and from below, is due to the projecting and carinated character of the radial plates. The base is trilobate in general outline, and excavated along the three sutures, the excavations being continued out beyond the base into the lower ends of three of the radial plates (Pl. XIX. fig. 14). Two of the basals are pentagonal and tricarinate, and one quadrangular and bicarinate, the carinæ projecting below the deeply sunken facet for the columnar attachment, so that when placed in its natural position the calyx stands on the carinæ like a tripod on its legs (Pl. XIX. fig. 13). The radial plates are very long and narrow, gradually taper upwards, are very prominent about the middle, and carinate below the lips. The deltoid plates are very small, and the summit openings closely approximate.

As we can now no longer regard *Stephanocrinus* as a member of the Blastoidea, *Tricœlocrinus* must be considered as the generic type, in which the peculiarities of the Blastoid base are most strikingly manifested. The distribution of its ridges has been already described on pp. 16–18; and the same arrangement may be traced on the base of many species of *Pentremites*, *Pentremitidea*, *Mesoblastus*, and *Codaster trilobatus* (Pl. IV. fig. 16; Pl. V. figs. 8, 11, 14, 29; Pl. VI. figs. 9, 14). In the last-named type (Pl. XIII. figs. 2, 13) there is an indication of the excavations along the interbasal sutures which reach their maximum in *Tricœlocrinus*. On the other hand, the lower end of the basal cup is cylindrical and not trihedral as in this type; though this latter character manifests itself very strongly in the allied genus *Metablastus*, especially in forms like *M. Varsouviensis* and *M. Wachsmuthi*. Neither of them, however, has the short and more or less truncate base with the deep hollows along the interbasal sutures which are so characteristic of *Tricœlocrinus Woodmani*, the type species of the genus (Pl. XIX. figs. 13, 14). These are less marked, though still distinct in our *Tricœlocrinus Meekianus* (Pl. XVI. figs. 17, 18), and also in *T. obliquatus*, Worthen and Meek, which is figured on pl. 31 of the sixth volume of the Illinois Geological Report. Fig. 4 *b* is a radial view showing the convergence of the two ridges 5 and 6 on to radial D, while 4 *d* shows the anal interradius. The figures 8 and 9 on the same plate, which represent *Pentremites Varsouviensis*, show no trace either of these ridges or of any intervening hollows in the base; and we are a little surprised therefore that the subgeneric name *Tricœlocrinus* should have been appended to the description of the species, which is said by the authors on p. 521 to be "closely allied" to *Pentremites*, i. e. *Metablastus*, *lineatus*.

[1] Report Geol. Survey Illinois, 1873, vol. v. p. 506.

By the kindness of Professors A. Gaudry and E. Perrier, of the Muséum d'Histoire Naturelle at Paris, we have been enabled to figure an excellent specimen of what appears to be *Tricœlocrinus Woodmani* (Pl. XIX. figs. 13–15). It has also been figured by Prof. Gaudry himself[1] under the name "*Pentremites* du groupe de *P. Wortheni*," in a radial view which shows the bifurcation of the median ridge at the lower end of radial D. The part of the plate enclosed within this bifurcation is all that he considers as the radial, while the rest of the body of the plate and its limb on either side are regarded as interambulacral pieces. We think, however, that Prof. Gaudry would scarcely have come to this conclusion if he had examined one of the other radials (C or E), in each of which the median ridge is continued straight down into an angle of the trihedral base (Pl. XIX. figs. 13, 14). The analogy of the radials of other Blastoids shows very clearly that their limbs cannot be regarded as interambulacral pieces, though we are quite disposed to agree with him in his view of the plates which he marks "aires interambulacraires" in *Elæacrinus*[2], as will be evident from what we have said on pp. 28, 29. But these plates in *Elæacrinus* are parts of the deltoids, and altogether different in character from the radial limbs of *Pentremites* or *Tricœlocrinus*, though occupying the same position as regards the ambulacra.

There is another point in Prof. Gaudry's figure of *T. Woodmani* about which we regret to have to differ from him. For it shows small deltoid pieces appearing externally above the truncated ends of the radial limbs just as in the figure of *Pentremites sulcatus* on the same page. We had returned the specimen to him before his book was published, and we therefore had no opportunity of comparing it with his figure; but so far as our own observations of it are concerned, we believe that the radial limbs extend right up to the summit and overlap the deltoid plates, as shown in Pl. XIX. figs. 13, 15.

The ambulacra of *Tricœlocrinus* are generally longer, and extend farther down the radials than those of either *Troostocrinus* or *Metablastus*, and for the greater part of their length the hydrospires beneath them are cut off from the body-cavity by extensions of the radial plates which close the sinuses below, *i. e.* the distal part of the sinus is not deep enough to penetrate through the thickness of the radial plate. We have already described this condition in three species of *Pentremites*[3] (Pl. II. figs. 13, 31; Pl. III. figs. 4–12; Pl. XVIII. figs. 7, 8). But it is carried to a much greater extent in *Tricœlocrinus*, so much so as to afford a character of considerable systematic value. It is very well shown in the large isolated radials of *Tricœlocrinus obliquatus*, Roemer, sp., which we take to be different from the species described under that

[1] Les Enchaînements du Monde Animal dans les Temps Géologiques. Fossiles Primaires (Paris, 1883), p. 89, fig. 57.

[2] *Ibid.* pp. 90, 91, fig. 60.

[3] See Chapter V. p. 95.

name by Messrs. Worthen and Meek. Figs. 10 and 11 on Pl. XVIII. represent the outer and inner faces of one of these radials; and the hydrospires are seen in fig. 11 to disappear within the substance of the radial a long way above the point which corresponds to the distal end of its ambulacrum. Fig. 13 is a sectional view of the piece of a D radial shown in fig. 12; and the shallowness of the radial sinus, as compared with the thickness of the plate, is well seen, as is also the very great reduction in the number of hydrospire-folds. This point is also well shown in a section of a smaller *Tricœlocrinus* from the Warsaw Limestone in Mr. Wachsmuth's collection (Pl. XVIII. fig. 9).

The spiracles of *Tricœlocrinus Woodmani*, the only species in which we have seen them at all satisfactorily, do not seem to be completely divided except on the anal side (Pl. XIX. figs. 15, 16), where they occupy the same relative position as those of *Metablastus lineatus* (Pl. III. figs. 14, 15).

Species. Four species of *Tricœlocrinus* are known to us, though it is possible that the first and third are identical.

Tricœlocrinus Meekianus, E. and C. Warsaw Limestone, Subcarboniferous: Indiana.

Pentremites obliquatus, Roemer. Subcarboniferous: Indiana.

Pentremites (*Tricœlocrinus*) *obliquatus*, Worthen and Meek. Warsaw Limestone, Subcarboniferous: Illinois.

Pentremites (*Troostocrinus*) *Woodmani*, Meek and Worthen. Keokuk Group?, and Warsaw Limestone, Subcarboniferous: Indiana.

Distribution. *Tricœlocrinus* is thus an essentially Carboniferous type, and so far as we at present know, it is limited to the Keokuk and St. Louis Groups of the American Carboniferous system.

Type. *Pentremites Woodmani*, Meek and Worthen.

TRICŒLOCRINUS OBLIQUATUS, *Roemer*, sp.

(Pl. XVIII. figs. 10–13.)

Pentremites occidentalis, Shumard, MS. (*fide* Roemer).

Pentatrematites obliquatus, Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. p. 367, t. 6. f. 11. *a* & *b*.

Pentremites obliquatus, Dujardin and Hupé, Hist. Nat. Zooph. Échinod. 1862, p. 97.

Tricœlocrinus obliquatus, E. & C., Ann. & Mag. Nat. Hist. 1883, vol. xi. p. 243.

Sp. Char. Radial plates very thick, elongate-oblong, or in the form of an elongated parallelogram with unsymmetrical ends, the marginal outline in one plane, but the surface highly arched and in two planes, which cut one another at the radial lips; bodies much shorter than the limbs, strongly bent down in the direction of the basiradial sutures, limbs long, having a much less marked median inclination than the

bodies, sides flat and highly inclined; sinuses very long, with steep sides; lips simple. not produced or overhanging; ornament consisting of close, slightly wavy subimbricating lines, following the outline of the plates; one or two impressed lines run parallel to the margins, producing a kind of border. Ambulacra very narrow, almost linear, tapering only at the extreme outer ends, lancet-plate quite concealed; side plates numerous, thirty-five and more; outer side plates tongue-shaped. Hydrospires very small, three on each side of an ambulacrum.

Remarks. Although Roemer only figured isolated radials of this species he mentioned that he had seen entire examples of it in the collection of Messrs. Yandell and Shumard at Louisville, and that the latter author had given it the MS. name of *P. occidentalis*. Unfortunately, however, Shumard never authenticated this name by either description or figure, and nothing is known of the rest of the calyx unless the type be identical with that which was subsequently described as *Tricœlocrinus Woodmani* by Meek and Worthen (Pl. XIX. figs. 13–16). But we are inclined to think that this is not the case.

Isolated radials of *T. obliquatus* occur in the National Collection (Pl. XVIII. figs. 10–13) and Prof. Roemer has kindly permitted us to examine his original types of the species. In our own specimens we cannot make out more than three hydrospire-folds on each side of the ambulacrum (Pl. XVIII. fig. 11); but in one of those belonging to Prof. Roemer there seem to be indications of a larger number.

After describing *Pentremites obliquatus*, Roemer pointed out [1] that the internal cast found by Owen and Shumard in Randolph County, Illinois, and described by them as *P. laterniformis* [2], "erinnert durch die verlängerte prismatische Gestalt des Kelches und durch die schmalen linearischen Pseudambulacral-Felder an den *P. obliquatus*, n. sp., obgleich die specifische Verschiedenheit nicht zweifelhaft ist." Shumard [3], however, expressed his belief that the cast *P. laterniformis* really is to be referred to *P. obliquatus*, Roemer; but we are inclined to doubt this, as no *Tricœlocrinus* is known in the Chester Group either at Randolph County, Illinois, or elsewhere; and we think it more probable that Hambach [4] is right in referring the cast to *Pentremites*, though not, we think, to *P. sulcatus*, for which it seems to us to be relatively too high, as we have explained on p. 156.

Roemer's specimens of *P. obliquatus* were obtained in Washington County, Indiana, and *P. laterniformis*, which he did *not* regard as identical with *P. obliquatus*, was found by Owen and Shumard in Randolph County, Illinois. But Messrs. Worthen and Meek [5] seem to have altogether misunderstood Roemer's remarks on the subject; for they say that *P. obliquatus* "also occurs in the Warsaw division of the St. Louis

[1] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 392.

[2] Wisconsin, Iowa, and Minnesota Geol. Report, 1852, p. 592, Tab. v. fig. 15.

[3] Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 384.

[4] *Ibid.* 1880, vol. iv. no. 1, p. 147.

[5] Report Geol. Survey Illinois, 1875, vol. vi. p. 521.

Group in Monroe County, Illinois, and not in the *Archimedes* beds of Randolph County, as cited by Roemer." We have some doubt whether the species which they figure under this name is identical with Roemer's type.

Locality and Horizon. Washington County, Indiana: St. Louis Limestone, Subcarboniferous.

Tricœlocrinus Meekianus, sp. nov.
(Pl. XVI. figs. 17, 18.)

Sp. Char. Calyx slender, elongately pyramidal; summit very small and very much contracted; base with shallow lateral excavations; section pentagonal, with straight or flat sides; periphery rather nearer the base than the summit. Basal plates forming a low triangular cup, with the three carinæ truncated, and not projecting below the central triangular surface which bears the facet for the columnar attachment. Radial plates with slightly converging lateral margins; bodies much shorter than the limbs, and moderately carinate, the lateral basal excavations extending but little on to their surfaces; limbs narrow with flat sides, not sloping at a high angle; sinuses three quarters the length of the calyx with high sides; interradial sutures not in concavities. Ambulacra rather deeply sunken. Hydrospires unknown; spiracles apparently mere slits only. Ornament not preserved.

Remarks. Although our specimen is entire, it is in a very bad state of preservation, and does not afford all the data which we could desire. We should unhesitatingly have referred this form to Worthen and Meek's *Tricœlocrinus obliquatus* [1] had it not been for two points of difference between it and their figures. The interradial sutures in the latter are placed in concavities, at least so we infer from the shading of the two illustrative figures; but in our specimen, the sutures in question are on flat surfaces and there are no interradial re-entering angles; while the ambulacra are relatively half as long again as in Worthen and Meek's species, and the base much less strongly hollowed (Pl. XVI. figs 17, 18). We do not think therefore that our species can be referred to Worthen and Meek's type; but, on the other hand, we greatly doubt whether the latter is identical with that previously described by Roemer under the same name.

We are a little in doubt about the deltoids of *T. Meekianus*, for there are some lines on the exterior of the calyx which might be thought to indicate that the deltoids appear externally (Pl. XVI. fig. 18). These are shown rather too plainly in our figure, and we suspect that they are really only cracks in the calcite, just as in the case of *Troostocrinus Reinwardti* and Shumard's specimen of *Metablastus lineatus*.

Tricœlocrinus Meekianus comes rather near to *Metablastus Wachsmuthi.* In fact these two species form the best connecting links between the two genera that we know of. The much longer ambulacra of the first-named, however, and the lateral

[1] Report Geol. Survey Illinois, 1875, vol. vi. p. 521, pl. 31. figs. 4*a*, 4*b*.

excavations of the base, together with the expansion of the lower part of the calyx, are sufficient to fix its generic position. It is an altogether smaller species than *Tricœlocrinus Woodmani*, which has a much more deeply excavated base.

Locality and Horizon. Spurgen Hill, Indiana: Warsaw Limestone, Subcarboniferous.

Family *NUCLEOBLASTIDÆ*, E. & C., 1886.

Definition. Calyx usually globular or ovoidal, with flattened or concave base and linear ambulacra. Spiracles distinctly double, and chiefly formed by the apposition of notches in the lancet-plate and deltoids.

Remarks. We have adopted the name Nucleoblastidæ for this family in order that the name *Nucleocrinus*, which was proposed by Conrad for its type genus, may not be altogether lost sight of. It is explained elsewhere why we cannot agree with Prof. J. Hall [1], who conceives "that there can be no doubt as to the propriety of restoring the earliest name" for the type which is now generally known as *Elæacrinus*, Roemer; and we have therefore done our best to prevent Conrad's notice of this form from being altogether forgotten.

The calyx is of a tolerably uniform shape among the different members of this family, being usually globular or ovoidal (Pl. II. figs. 43, 46; Pl. VI. fig. 15; Pl. VIII. fig. 10; Pl. XIII. fig. 18; Pl. XVI. fig. 13; Pl. XVIII. fig. 19), though it lengthens out considerably in *Elæacrinus obovatus*, Barris. The base is relatively small and either flattened or concave (Pl. II. fig. 45; Pl. VI. fig. 17; Pl. XIII. fig. 17); while, except in *Acentrotremites* (Pl. XIII. figs. 18, 19), the ambulacra are narrow and linear, as the side plates rest upon and not merely against the lancet-plate (Pl. VIII. fig. 11; Pl. X. fig. 17; Pl. XVII. figs. 1, 19; Pl. XVIII. figs. 16–18). The spiracles are largely formed by notches in the flattened proximal ends of the deltoid plates (Pl. III. figs. 1–3; Pl. VI. fig. 16; Pl. VII. figs. 14, 15; Pl. XVI. fig. 12; Pl. XVIII. fig. 16) except in *Acentrotremites*, which has its spiracles on the lines of the radio-deltoid sutures (Pl. XIII. figs. 18, 19). In this type, as also in *Cryptoblastus* and *Elæacrinus* (Pl. VII. fig. 15; Pl. XVIII. fig. 16), the lancet-plate is likewise more or less incised, and so helps to increase the size of the spiracle; but this is not so clearly the case in *Schizoblastus* (Pl. III. fig. 3). The spiracles of this last genus are formed on somewhat the same plan as those of *Metablastus* (Pl. III. figs. 14, 15; Pl. VI. fig. 16); but on the other hand the Irish species of it (Pl. VIII. fig. 9; Pl. XVI. fig. 12) have a summit not unlike that of *Mesoblastus*, from which, however, they may be distinguished by the absence of an hydrospire-plate. *Mesoblastus* thus forms a link between the Pentremitidæ and the

[1] Fifteenth Ann. Rep. New York State Cab. Nat. Hist., Albany, 1862, p. 145.

Nucleoblastidæ, which are perhaps also connected with *Granatocrinus* through the medium of *Heteroblastus* (Pl. VI. figs. 2–4).

The division of the posterior deltoid of *Elæacrinus* into two parts by the intercalation of an anal plate (Pl. XVIII. fig. 19) is such an unusual feature in Blastoid morphology, that we have been led to remove this type from the other three members of the family, and to place it in a subfamily by itself, which we propose to call Elæacrinidæ. It must be remembered, however, that superficial markings, indicative of a similar triple division of the interradius, are shown on the other four deltoids of *Elæacrinus* and often also on all those of *Schizoblastus Sayi*, as we have pointed out on p. 35. In this species, and possibly also in *S. melonoides*, the only other American type which we can definitely refer to this genus (Pl. III. fig. 3; Pl. VI. fig. 16), the posterior spiracles are separate from the anus, as in *Elæacrinus* (Pl. XVIII. fig. 16); but those of the Irish species *S. Rofei* and *S. Bailii* (Pl. VIII. fig. 9; Pl. XVI. fig. 12) are confluent with the anus as in *Cryptoblastus* and *Mesoblastus* (Pl. VI. figs. 7, 8, 13; Pl. VII. figs. 14, 15). In the latter genus, however, the side plates form the distal border of the spiracle, which is not the case in the Nucleoblastidæ.

i. Subfamily. ELÆACRINIDÆ, *E. & C.*, 1886.

Definition. Posterior deltoid divided into two parts by an anal plate. Anus distinct from the posterior spiracles.

Genus ELÆACRINUS, *F. Roemer*, 1851 (emend. Hall, 1862).

Nucleocrinus, Conrad, Journ. Acad. Nat. Sci. Philad. 1842, vol. viii. pt. 2, p. 280.
Olivanites, Troost (MS.), American Journ. Sci. 1849, vol. viii. p. 419.
Olivanites, Troost (MS.), Proc. American Assoc. Adv. Sci. for 1849 [1850], p. 62.
Elæacrinus, Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 375.
Elæacrinus, Roemer in Bronn's Lethæa Geogn., Dritte Aufl. 1852–54, Theil ii. p. 283.
Nucleocrinus, Hall, Fifteenth Ann. Report New York State Cab. Nat. Hist. 1862, pp. 144 and 146.
Elæacrinus, Dujardin & Hupé, Hist. Nat. Zooph. Échinod. 1862, p. 100.
Elæacrinus (pars), Shumard, Trans. St. Louis Acad. Sci. 1863, vol. ii. no. 1, p. 111.
Elæacrinus, Shumard, ibid. 1865, vol. ii. no. 2, p. 368.
Nucleocrinus, Meek & Worthen, Report Geol. Survey Illinois, 1866, vol. ii. p. 275.
Nucleocrinus, Billings, American Journ. Sci. 1870, vol. l. p. 229.
Eleacrinus, E. & C., Ann. & Mag. Nat. Hist. 1883, vol. xi. p. 228.

Gen. Char. Calyx ovate-oblong, olive-shaped, or elliptical, usually more attenuated towards the base, but enlarging above the basi-radial sutures with a graceful swelling outline: summit flat, rounded, or slightly concave; base excavated (except in one species), the calyx supported on the radial lips when in a vertical position; plates usually anchylosed; section pentagonal, with concave or nearly round sides, and

sometimes approaching to decagonal, with straight sides. Basal plates small and inconspicuous, invisible in a side view, and hidden within the columnar cavity. Radial plates small, forming a low expanded cup or basin ; limbs short, with the proximal margins scalloped ; bodies greatly reduced in size, distally reflected within the columnar pit; lips prominent, constituting a quinquepod on which the calyx rests. Deltoid plates greatly enlarged and elongated, usually lanceolate, forming quite or more than two thirds of the entire calyx; anal interradius wider than the others, more prominent, giving to the body a slightly unsymmetrical outline, its deltoid being divided into two parts by an anal plate ; each of the other deltoids is superficially divided into three parts by two more or less distinctly impressed lines parallel to the margins of the plate. Radio-deltoid sinuses narrow, extending the whole length of the calyx from the summit to the base, the radial portions very short and shallow. Ambulacra similar in size and length, sometimes prominent, almost entirely enclosed by the deltoid plates; lancet-plates exceedingly long and very narrow, but entirely filling the radio-deltoid sinuses, and partially exposed ; side plates and outer side plates numerous, sometimes almost ninety in number. Hydrospires pendent, two tubes on each side of an ambulacrum ; spiracles ten in number, arranged in five pairs, which notch the proximal ends of the deltoid plates. Mouth large when exposed, but normally closed by five or more summit plates which form a flattened dome above the peristome. Anus more or less horizontal in position, closed by one or more plates, and distinct from the posterior spiracles, which are somewhat smaller than their fellows. Column round or imperfectly pentagonal. Ornament " striato-cancellate, or striato-granulose."

History. The generic value of this type was first noticed by Conrad [1], who gave an imperfect description of it in 1842 under the name of *Nucleocrinus*. His description, which was accompanied by a figure of his type species *N. elegans*, runs thus:—" This genus differs from *Pentremites*, Say, in having only one perforation at the top, which is central."

In 1849 Dr. G. Troost [2] gave a list of fossil Crinoids found in Tennessee. Amongst these occurs the name *Olivanites Verneuili*, but it is unaccompanied by any generic description. In the year 1851, however, Dr. F. Roemer [3] published an elaborate account of this fossil, and showed that it represented a new generic type, for which he proposed the name of *Elœacrinus*. A few years later, however, Lyon [4] came to the conclusion that Roemer's material had not been sufficiently well preserved, and that in consequence of this " both the figures and description are defective in many respects. For these reasons, and possessing quite perfect specimens,

[1] Journ. Acad. Nat. Sci. Philad. 1842, vol. viii. pt. 2, p. 280, pl. xv. fig. 17.

[2] American Journ. Sci. 1849, vol. viii. p. 419.

[3] Archiv f. Naturgesch. 1851, Jahrg. xviii. Bd. 1, p. 375.

[4] Palæontological Report, Owen's 3rd Report Geol. Survey Kentucky, 1857, p. 487.

it is proposed to describe these, and restore the name proposed by that pioneer of Western geology, Dr. Troost." Conrad's name appears to have been entirely unknown to Lyon, whose analysis of the calyx was far more elaborate than that given by Roemer, and, except in one point, has not met with general acceptance.

Two years later Messrs. Lyon and Casseday in their "List of Palæozoic Echinodermata of North America"[1] pointed out the identity of *Nucleocrinus*, Conrad, *Olivanites*, Troost, and *Elæacrinus*, Roemer[2]; and they abandoned Troost's name in favour of that previously proposed by Conrad, *Olivanites* and *Elæacrinus* being thus reduced to the rank of synonyms.

Three years later the same course was taken by Hall[3], who made no reference, however, to Messrs. Lyon and Casseday. He carefully excluded from *Elæacrinus*, or, as he termed it, *Nucleocrinus*, such species as *Pentremites Norwoodi*, O. & S., and *P. melo*, O. & S., which have a calyx very similar in form to that of *Elæacrinus*, though, so far as we are aware, neither Roemer nor any one else had ever proposed to place them in this genus. He altogether ignored Lyon's analysis of the calyx, but gave one of his own which, except for one important point (the intercalated anal plate), is almost identical with that previously published by Roemer.

The next year (1863), Dr. F. B. Shumard, in a paper entitled "Descriptions of new Palæozoic Fossils,"[4] also suggested the probable identity of *Nucleocrinus* and *Elæacrinus*, but he included therein most of those Blastoids which form Roemer's group *Elliptici* (i. e. *Granatocrinus* and *Cryptoblastus*, as we now understand them). Shumard's previously conceived views were, however, changed in 1865[5], when he restricted *Elæacrinus* within much the same limits as were originally proposed by Roemer. In the same year those accomplished Palæontologists, Messrs. Meek and Worthen, clearly laid down the characters which separate this genus from *Granatocrinus*[6] as typified by *G. Norwoodi* and *G. melo*[7].

We now come to the views of *Elæacrinus* which were expressed by the late Mr. Billings in his note, "On the Structure of the Genus *Nucleocrinus*."[8] He adopted and supported the theory of Mr. S. S. Lyon, regarding the presence of a second series of concealed basal plates; while he also described the interradial plates as quite small and as bounded by marginal pieces which belong to the ambulacra.

The genus *Nucleocrinus* and Hall's diagnosis of it were accepted by Montgomery[9]

[1] Proc. American Acad. 1859, vol. iv. p. 283. [This volume bears date 1860, and is for the period extending from May 1857 to May 1860. Shumard, however, in his "Catalogue of the Palæozoic Fossils of North America.—Part 1. Echinodermata" (Trans. St. Louis Acad. Sci. 1865, p. 334), gives the date 1859 to Lyon and Casseday's paper (*l. c.* p. 369), which we here adopt.] [2] *Ibid.* p. 295.

[3] Fifteenth Ann. Rep. New York State Cab. Nat. Hist. 1862, p. 146.

[4] Trans. St. Louis Acad. Sci. 1863, vol. ii. no. 1, p. 112. [5] *Ibid.* 1865, vol. ii. no. 2, p. 363.

[6] Report Geol. Survey Illinois, 1866, vol. ii. p. 275.

[7] This species is erroneously described as having single spiracles perforating the deltoids.

[8] American Journ. Sci. 1870, vol. l. p. 229.

[9] Canadian Nat. & Geol. 1881, vol. x. no. 2, p. 80.

in 1881; while in 1883 we gave our reasons [1] for adopting Roemer's name *Elæacrinus* with the modified analysis of the calyx as suggested by Hall, and the same course was taken by Barris [2] soon afterwards.

Remarks. It appears to us that there can be no question as to the justice of employing Roemer's name for this generic type in preference to that proposed by Conrad, who regarded the basal concavity as a single "perforation at top." It was by this character only that he distinguished *Nucleocrinus* from *Pentremites*, which has five summit-openings round the central mouth. Roemer gave a full description of *Elæacrinus* in 1851, and it was not until the publication of Hall's observations in 1862 that the nature of *Nucleocrinus*, as typified by *N. elegans*, Conrad, was satisfactorily known [3]. But although it subsequently appeared that *Elæacrinus Verneuili* and *Nucleocrinus elegans* are congeneric, Hall considered "that there can be no doubt as to the propriety of restoring the earliest name," i. e. *Nucleocrinus*.

We entirely dissent from this proposition, and feel it only right to adopt Roemer's name, as has been already done by Shumard [4], with the following remarks:— "Strictly adhering to the laws which govern naturalists in such cases, we cannot in justice to Roemer set aside his name. The description of Conrad was not only extremely imperfect, but it is entirely erroneous and calculated to mislead the student in his efforts to identify the fossil he attempted to describe. In a word, no one could possibly recognize the genus from Conrad's description, since there is no section of the family Blastoidea presenting such a structure."

We are inclined to accept as correct the analysis of the calyx of *E. Verneuili* as given by Roemer, with the modification introduced by Hall. But in other respects we have little doubt that the one given by the German Palæontologist is the most generally accurate of any which have hitherto appeared. Lyon believed himself to have discovered that below the pieces which Roemer described as basals there are three yet smaller ones, separating them from the top stem-joint, and also interradial in position. In accordance with his peculiar system of nomenclature, he transferred the name "basals" to these plates, and called the basals of Roemer "primary radials," although they are only three in number and are not situated in the direction of the rays (Pl. II. fig. 45); while the fork-pieces or true radials were called by him "primary radials, second series." Lyon's description was accepted by Billings, who corrected the errors in his terminology, and pointed out that the six plates described by Lyon as basals and as primary radials together correspond "to the six pieces which constitute the compound basal plates of *Pentremites*." But

[1] Ann. & Mag. Nat. Hist. 1883, vol. xi. p. 229. [2] Report Geol. Survey Illinois, 1883, vol. vii. p. 357.

[3] In a paper which was published in the following year (1863), Shumard said, "It is possible that the genus *Nucleocrinus*, proposed by Conrad in 1842, may be identical with *Elæacrinus*; but the meagre and unsatisfactory description of Conrad does not apply to any of the forms we propose to group in *Elæacrinus*." (Trans. St. Louis Acad. Sci. 1863, vol. ii. no. 1, p. 112.)

[4] Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 368, note.

neither Hall, Montgomery, Zittel, nor Barris makes any mention of this double series of basal plates; and we have been equally unable to find any satisfactory evidence of their presence. There is, however, an impression on the lower face of the basals which corresponds to the upper stem-joint (Pl. II. fig. 45); but this is nothing more than occurs in a large number of Crinoids, and we see no reason whatever for regarding it as indicating the presence of a ring of "supplemental basals."

Great misconception appears to have arisen concerning the deltoid plates in this genus. Lyon and Billings supposed them to be only the lanceolate centres of each interradius, "separated from the pieces on either side of the pseudambulacræ by a sharply defined angular ridge, surrounding the whole piece, &c."[1] These lateral pieces according to their view were attached portions of the ambulacra, and were even supposed by Billings to overlap the central lanceolate portions, the latter being provided with bevelled edges for their reception. It is almost needless to observe that did such "ambulacral plates" exist, as described by Lyon and Billings, we should have an arrangement altogether at variance with anything in the structure of the Blastoidea, as it is at present known to us. Nor does it exist in fact, for we are quite convinced that the four anterior interradii of *Elæacrinus* are perfectly normal in character (Pl. II. figs. 43, 44, 46); though we admit the presence of an anal plate as described by Hall. Lyon and Billings were led astray by the diversity of the ornamentation on different parts of the same plate, by the longitudinal surface grooves marking off a middle lanceolate portion of each deltoid, and perhaps also by their preconceived ideas of ambulacral structure.

The surfaces of the deltoid plates adjoining the ambulacra on each side of the radio-deltoid sinuses are transversely grooved for a short distance (Pl. II. fig. 46; Pl. XVIII. figs. 17, 18). This portion is the "broad transversely grooved marginal plate" of Billings, and the "piece ornamented with grooves and ridges" of Lyon. It is true that these lateral portions of the deltoids are grooved, and Lyon and Billings are equally correct in saying that each of the grooves and intervening ridges corresponds to a pore and a plate of an ambulacrum. But these structures are nevertheless integral portions of the deltoid plates, and are scarcely apparent except in weathered specimens. Examples of *Elæacrinus* are frequently found with the radio-deltoid sinuses empty and the component parts of the ambulacra lost. If, therefore, these lateral portions of the deltoids really belonged to the ambulacra, we should expect to find them also absent in such weathered individuals; but this is by no means the case. Then, again, in well-preserved examples of *E. Verneuili* the grooves and ridges gradually die out towards the summit; one portion of the ambulacrum, therefore, would be provided with such additional plates, and other parts not.

The structure of the anal interradius in *Elæacrinus* is peculiar and unusual. Lyon described it as occupied by an "anal piece" which is wider than the other four

[1] Palæontological Report, Owen's 3rd Report Geol. Survey Kentucky, p. 490.

interradial pieces; while Hall[1] said, "A narrow intercalated plate on the anal side reaches from the aperture to the radial plate, dividing the interradial on that side into two narrow curving plates." Or, in the still clearer words of Meek and Worthen:—"We find the area between two of the pseudo-ambulacra on the anal side wider, and often more prominent above than the other interambulacral spaces, and occupied by three large elongated pieces, the middle one of which, the anal piece, is lanceolate in form, and with the two interradials fills all the large anal area down to the base."[2]

We are inclined to believe that this is really the case, as do Montgomery[3] and Barris[4], the latest writers on the subject. Dr. J. G. Hinde has favoured us with the loan of a specimen of *E. Canadensis*, Montg., in which the sutures of this complex plate (Pl. XVIII. fig. 19) are beautifully shown. The sides of the anus are excavated out of the lateral portions of the anal deltoid, and the distal margin out of the central plate. The latter appears to overlap the two side pieces, and to lie on them to a certain extent. Lyon's description of the tripartite structure of the interradii has thus proved to be correct for that of the anal side; though what we now know to be the parts of the divided anal deltoid were regarded by him as belonging to the ambulacra.

The summit-plates are often arranged with a singular regularity, which is much more apparent than is usually the case in other Blastoids. Roemer figured seven in *E. Verneuili*, one in the centre and six peripheral. These were also mentioned by Lyon, together with fifteen others, the nature of which is by no means clear from his description of them. According to Hall the summit is occupied by five or more plates, while one of our own specimens of *E. Verneuili* shows a central one immediately surrounded by seven others, with smaller ones outside them (Pl. XVIII. fig. 16). These summit-plates appear to be larger and less numerous in *Elæacrinus* than they often are in *Schizoblastus* (Pl. III. fig. 3) or in *Orophocrinus* (Pl. XV. fig. 12), and are therefore of considerable morphological importance, as we have explained on pp. 73–75.

We are able to confirm Billings's account of the two hydrospires on each side of the ambulacra of *E. Verneuili* (Pl. XVII. fig. 19), and have also been able to make out the water-vascular ring with the radial trunks proceeding from it (Pl. XIX. fig. 7), just as in *Pentremites* (Pl. XII. figs. 16, 17).

Species[5]. Want of material prevents us giving a critical list of species, but the following have been described under one or other of the three names which have been bestowed on this generic type:—

[1] Fifteenth Ann. Rep. New York State Cab. Nat. Hist. 1862, p. 146.

[2] Report Geol. Survey Illinois, 1866, vol. ii. p. 275.

[3] Canadian Nat. & Geol. 1881, vol. x. no. 2, p. 82.

[4] Report Geol. Survey Illinois, 1883, vol. vii. p. 858.

[5] We omit from this list the *Elæacrinus Kirkwoodensis*, Shumard, formerly included by us.

Olivanites angularis, Lyon. Corniferous Limestone, Lower Devonian; Kentucky, Ohio.

Nucleocrinus Canadensis, Montg.[1] Hamilton Group, Upper Devonian; Ontario.

Nucleocrinus Conradi, Hall[2]. Upper Helderberg Group, Lower Devonian; New York State.

Nucleocrinus elegans, Conrad. Hamilton Group, Upper Devonian; New York State.

Nucleocrinus lucina, Hall. Hamilton Group, Upper Devonian; New York State.

Elæacrinus meloniformis, Barris. Hamilton Group, Upper Devonian; Michigan.

Elæacrinus obovatus, Barris. Hamilton Group, Upper Devonian; Michigan, Iowa, and New York State.

Pentremites Verneuili, Troost (MS.). Corniferous Limestone, Lower Devonian; Kentucky, Ohio.

Distribution. Elæacrinus is purely a Devonian genus, and appears to be generally distributed throughout that formation in the United States and Canada, but is unknown in rocks of a similar age in Europe. There appear to be no species common to the Lower and Upper Devonian.

Type. Pentremites Verneuili, Troost.

Elæacrinus Verneuili (*Troost*, sp., MS.), *Roemer*.

(Pl. II. fig. 45; Pl. XVII. fig. 19; Pl. XVIII. figs. 16–18; Pl. XIX. fig. 7.)

Pentremites Verneuili, Troost (MS.), 6th Report Geol. State Tennessee, 1841, p. 14.

Pentremites Verneuilii, D'Orb., Prod. Pal. Strat. 1849, i. p. 102.

Olivanites Verneuilii, Troost (MS.), American Journ. Sci. 1849, vol. viii. p. 419; Proc. American Assoc. Adv. Sci. for 1849 [1850], p. 62.

Elæacrinus Verneuilii, Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 379, t. 8. f. 1, *a–d*.

Olivanites Verneuilii, Lyon in Owen's 3rd Report Geol. Survey Kentucky, 1857, p. 487, t. 5. f. 1, *a–d*.

Pentremites Verneuilii, Shumard, Trans. St. Louis Acad. Sci. 1858, vol. i. no. 2, p. 247.

Elæacrinus Verneuilii, Roemer in Bronn's Lethæa Geogn., Dritte Aufl. 1852–54, Theil ii. p. 284, 4. f. 10, *a* & *b*.

Nucleocrinus Verneuili, Lyon and Casseday, Proc. American Acad. 1859, vol. iv. p. 295.

Elæacrinus Verneuili, Bronn, Klassen und Ordn. Thier-Reichs, 1859, Bd. i. t. 23. f. 5, A–E.

Elæacrinus Verneuillii, Dujardin and Hupé, Hist. Nat. Zooph. Échinod. 1862, p. 100.

Elæacrinus Verneuili, Shumard, Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 369.

Nucleocrinus Verneuilii, Billings, American Journ. Sci. 1870, vol. l. p. 229, f. 3–6.

Elæacrinus Verneuili, E. & C., Ann. & Mag. Nat. Hist. 1883, vol. ix. p. 231.

Sp. Char. Calyx olive-shaped, roundly ellipsoidal, more attenuated below than above; summit flat or a little concave; base contracted, with a deep pentagonal

[1] Montgomery thinks this may be a var. of *E. lucina,* Hall, sp.

[2] Hall says perhaps a var. of *E. Verneuili.*

columnar cavity; section nearly round; periphery almost equatorial. Basal plates small, entirely hidden within the columnar cavity, and forming a small inverted cup. Radial plates very short with scarcely any subdivision into bodies and limbs, their distal ends bent inwards; basiradial sutures within the columnar cavity; lips prominent, and horizontally projecting, each with a backwardly directed ridge running to the edge of the columnar cavity, within which the ridges are continued, two being less prominent than the other three. Deltoid plates occupying two thirds the length of the calyx, stave-shaped, central portion of each plate raised a little above the lateral parts; anal plate more prominent than the central portions of the four normal deltoids, and separate from the lateral portions of the azygos one, horizontally truncated at the proximal end, in some specimens projecting above the summit, in others depressed below it; radio-deltoid sinuses narrow, and as long as the calyx, but the radial portions remarkably short. Ambulacra very long and narrow, with parallel sides, and projecting above the edges of the sinuses; side plates quadrangular, at least 60 on each side of an ambulacrum; outer side plates oblong, or tear-shaped; hydrospire-pores very large; lancet-plate exposed only in the ambulacral groove. Hydrospire-folds two; the sacs pyriform. Spiracles oval, opening obliquely upwards and inwards towards one another in pairs, their outer margins elevated and rim-like. Mouth small, covered by a variable number of summit-plates arranged round a central one. Anus oval, opening more or less in two planes, the proximal portion being oblique to the summit, and the distal half of the opening horizontal, with a prominent margin. Column unknown. The lateral portions of each deltoid plate are cancellated, the central portions granulose, with occasional wavy chevron-like undulations corresponding to the outline of the radio-deltoid suture; the radial plates have similar markings.

Remarks. We have experienced no little difficulty in deciphering the mutual relations of the various parts of the calyx in *Elæacrinus Verneuili*—the "petrified hickory nut" of Lyon. This is due to the highly silicified nature of most of our specimens, but we believe our explanation to be substantially correct.

The typical form of this species, as figured by Lyon, is olive-shaped, but it passes through an almost endless series of insensible gradations of outline up to the marked variety which we shall presently describe under the name of *Elæacrinus Verneuili*, var. *pomum*. Troost proposed another species, *Olivanites globosus* [1], but both Roemer [2] and Shumard [3] refer this to *E. Verneuili* as a synonym. The latter author also places here the *Pentremites carioides*, D. D. Owen; but we have not had access to the work [4] in which this is described (? or mentioned only).

Little difficulty will be experienced in distinguishing between *E. Verneuili* on the

[1] Proc. American Assoc. Adv. Sci. for 1849 [1850], p. 62.

[2] Bronn's Lethæa Geogn., Dritte Aufl. 1852–54, Theil ii. p. 284.

[3] Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 369.

[4] Cat. Geol. Specimens Ohio Valley, 1843.

one hand, and *E. elegans*, Conrad, sp., and *E. lucina*, Hall, sp., on the other, after Hall's expressive figures of the two latter types. *E. Conradi*, Hall, sp., can hardly be said to be described; but if the protruding base to which Hall refers is a constant and not merely an accidental character, herein lies a good point of separation from all other species of the genus. We very much doubt if *E. Kirkwoodensis*, Shumard, belongs to the present genus. At the time Shumard described this species he entertained very elastic views about *Elæacrinus*, and it is possibly either a *Cryptoblastus* or a *Schizoblastus.* Indeed the description of the "radial pieces ..... occupying more than four fifths the entire length of the body" is fatal to any possibility of an affinity with *Elæacrinus*; and Shumard's statement that *E. Kirkwoodensis* is nearly allied to *E.* (*Pentremites*) *melo*[1] is suggestive of its generic relations with *Cryptoblastus. E. angularis*, Lyon, is easily distinguished by its markedly pentagonal outline (Pl. II. figs. 43, 44); *E. obovatus*, Barris, is so greatly elongated vertically that it can hardly be mistaken for any other species; and Barris's other species, *E. meloniformis*, is described as being smaller than *E. Verneuili* and most closely allied to *E. elegans.* Lastly, *E. Canadensis*, Mont., sp., is certainly distinct from *E. Verneuili.* It may be a variety of *E. lucina*, as suggested by Mr. Montgomery, but after an examination of Dr. Hinde's specimen (Pl. XVIII. fig. 19), we are inclined to regard it as a distinct species. The ornamentation is certainly different from that of *E. Verneuili.*

Locality and Horizon. Falls of the Ohio, near Louisville, Kentucky; Columbus, Ohio (Presented by Prof. H. A. Nicholson, M.D.): Corniferous Limestone, Lower Devonian. Clarke County[2], Indiana: Upper Helderberg Group, Lower Devonian.

According to Mr. S. S. Lyon *E. Verneuili* is found in "rocks of the Devonian period, about five or six feet below the hydraulic cement beds, in a rock of peculiar physical character, distinguished as the Olivanite bed ..... The beds at the Falls of the Ohio have probably been the most productive"[3].

Elæacrinus Verneuili, var. pomum, *var. nov.*

(Pl. II. fig. 46.)

Remarks. We desire to separate from the typical form of *E. Verneuili*, as figured by Roemer, Lyon, Bronn, and Billings, that variety which is distinguished by an almost globular or round calyx. It does not possess the elongated nut-like form of the figures given by the above-named authors, although it presents essentially the same morphological characters. There is such a wide difference of form between the original of our Pl. II. fig. 46 and Roemer's or Lyon's type, that many would consider it a sufficient reason for elevating the former to specific rank. We have, however,

[1] Trans. St. Louis Acad. Sci. 1863, vol. ii. no. 1, p. 113.

[2] Lyon says Silver and Fourteen-mile Creeks.

[3] 'Palæontological Report,' Owen's 3rd Report Geol. Survey Kentucky, 1857, p. 492.

seen so many intermediate gradations between the two that we can only look upon them as the extreme limits of one very variable species.

It is not impossible that such a form as that now referred to may have represented Troost's *Olivanites globosus.*

Locality and Horizon. Columbus, Ohio (Presented by Prof. H. A. Nicholson, M.D.): Corniferous Limestone, Lower Devonian. Clarke County, Indiana: Upper Helderberg Group, Lower Devonian.

ELÆACRINUS ANGULARIS, *Lyon*, sp.

(Pl. II. figs. 43, 44.)

Olivanites angularis, Lyon, Owen's 3rd Report Geol. Survey Kentucky, 1857, p. 492, t. 5. f. 2 *a–b*.

Nucleocrinus angularis, Lyon and Casseday, Proc. American Assoc. Adv. Sci. 1859, vol. iv. p. 295.

Elæacrinus angularis, Shumard, Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 368.

Elæacrinus angularis, E. & C., Ann. & Mag. Nat. Hist. 1883, vol. xi. p. 231.

Sp. Char. Calyx pentagonal-subovoid, inflated along the lines of the ambulacra; summit flattened; base contracted; section pentagonal, the sides concave; periphery a little more than a third from the summit. Deltoid plates ellipsoidal, concave below but becoming flattened towards the summit; each plate divided into three parts by two impressed lines diverging from the upper end, and leaving the central spaces lanceolately triangular; radio-deltoid sinuses very narrow, and much arched. Ambulacra similar, and protruding above the edges of the sinuses. Spiracles slit-like. Central summit-plates very small, and numerous.

Remarks. We are unable to afford further particulars of this species from the fact that our only specimen is imperfect, and partially imbedded in limestone. Three ambulacra and the corresponding interradial areas, with a portion of the summit, are all that is exposed. The pentagonal section and the great arching of the ambulacra, however, clearly indicate its specific identity with Lyon's type.

Locality and Horizon. Unknown. [Lyon gives the Falls of the Ohio, Kentucky; Beargrass and Silver Creeks, Clare County, Indiana: Lower Devonian, as the localities and horizon.] Our specimen is probably from one or other of these places.

ELÆACRINUS, sp.

Remarks. The Collection contains a fragment of what must have been quite a large species of *Elæacrinus.* It is an anal interradius, more than one and a quarter inches in length, and differs much in shape from the corresponding part both of *E Verneuili* and of *E. angularis.* It is not, however, too large for the anal interradius in *E. obovatus*, Barris, and may possibly belong to that species. The lateral portions of the deltoid are cross-ridged in the usual way, and the plate is microscopically vermicular-striate.

Locality and Horizon. The specimen is preserved in a light-coloured crystalline limestone of unknown locality. It is said to have come from "Cincinnati, Ohio;" but this is clearly erroneous.

ii. Subfamily. SCHIZOBLASTIDÆ, *E. & C.*, 1886.

Definition. No anal plate. Posterior spiracles may be fused with the anus.

Remarks. All the three genera which we include in this subfamily differ from *Elæacrinus*, and resemble every other Blastoid in the absence of an anal plate. In *Acentrotremites* and in the only two American species of *Schizoblastus* which we have seen, the posterior spiracles open separately from the anus, as they do in *Elæacrinus* (Pl. III. fig. 1; Pl. XIII. fig. 19); but in *Cryptoblastus* and in the two Irish species of *Schizoblastus* there is a common anal spiracle as in the Pentremitidæ (Pl. VII. fig. 14; Pl. VIII. fig. 9; Pl. XVI. fig. 12). The other differences between these three genera are expressed in the following scheme.

A. Spiracles at or near the proximal ends of the deltoids. Lancet-plate not completely concealed by the side plates.

1. Hydrospire-pores along the edges of the deltoids. No hydrospire-plate.	*Schizoblastus*, E. & C.
2. No hydrospire-pores along the edges of the deltoids. An hydrospire-plate.	*Cryptoblastus*, E. & C.
B. Spiracles on the radio-deltoid sutures. Lancet-plate completely concealed by the side plates.	*Acentrotremites*, E. & C.

Genus SCHIZOBLASTUS, *E. & C.*, 1882.

Granatocrinus (pars), Shumard[1], Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 375.
Granatocrinus (pars), Meek and Worthen, Report Geol. Survey Illinois, 1866, vol. ii. p. 274.
Schizoblastus (pars), E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 243.

Gen. Char. Calyx resembling that of *Granatocrinus* in form, globose, pentagonal-globose, or melon-shaped; summit contracted and flattened, or a little concave, truncate or slightly protuberant; section pentagonal, or decagonal. Basal plates almost always confined to the base, but sometimes just visible in a side view. Radial plates may be either very long, or exceedingly short, and incurved below to assist in forming the base. Deltoid plates of variable size, but always visible in a side view. Ambulacra narrow and sublinear, extending along the whole height of the calyx; lancet-plates sometimes largely concealed by the side plates, though not completely so; side plates from twenty to about eighty in number. One to four hydrospire-

[1] Et auctorum.

folds on each side of an ambulacrum. Spiracles small, appearing as linear slits between the lancet-plate and the deltoid ridges, which are of variable width. The posterior pair may open separately at the sides of the anus, beneath a kind of hood formed by the deltoid plate, or be confluent with it, so as to form one large anal spiracle. Surface usually much ornamented with granular striæ. Column circular.

History. The species which we have taken as the type of this genus was described by Shumard [1] by the name of *Pentremites Sayi*, though he stated that it "presents all the essential characters of the genus *Elæacrinus*, Roemer." In this respect he was perfectly correct, for the presence of an anal plate in the posterior interradius of *Elæacrinus* had not then been discovered. Later on, however, the species was referred to both by Shumard and by Messrs. Meek and Worthen as *Granatocrinus Sayi*, and it has been generally known by this name in America. For all Blastoids (except *Elæacrinus*) with linear ambulacra extending along the whole length of a globose or ovoid calyx were referred to this genus, whether they had five spiracles piercing the deltoids or ten "excavated, one into each lateral margin of these pieces" [2].

This important difference had not, however, escaped the notice of Messrs. Meek and Worthen, though they never gave a definite expression to their views by proposing a new generic name. This step was taken by ourselves in 1882, when we took *Pentremites Sayi*, Shumard, as the type of a new genus *Schizoblastus*, and we referred to it all the American species of *Granatocrinus* which have the spiracles in pairs at the sides of the deltoid plates, and not piercing their central ends.

Further investigation, however, has led us to separate off two of these under the generic name *Cryptoblastus*, while two others will probably fall into the new genera *Mesoblastus* and *Heteroblastus*, which we have established for certain British Blastoids. This has rendered us very uncertain as to the generic position of species which we have not personally examined; and the only American species which we can definitely refer to *Schizoblastus*, in addition to *Pentremites Sayi*, Shumard, is the *Granatocrinus melonoides* of Meek and Worthen. On the other hand we must now transfer to *Schizoblastus* an Irish species which we formerly referred with doubt to *Granatocrinus* (*G. Rofei*), and we can further add a fourth species also from Ireland (*S. Bailii*).

Remarks. The calyx of *Schizoblastus* is either subglobose as in *S. Sayi* and *S. Bailii* (Pl. XVI. fig. 13), and in a less degree in *S. Rofei* (Pl. VIII. fig. 10), or more elongated and melon-shaped as in *S. melonoides* (Pl. VI. fig. 15). In the first-named species the section is fairly pentagonal, but in the other three it is rather more decagonal (Pl. VI. figs. 16, 17; Pl. VIII. fig. 9; Pl. XVI. fig. 12). The

[1] 'Palæontological Report,' Swallow's First and Second Annual Report, Geol. Survey Missouri, 1855, pt. 2, p. 185.

[2] Report Geol. Survey Illinois, 1866, vol. ii. p. 274.

base resembles that of *Granatocrinus* in being small and flattened, or slightly concave (Pl. VI. fig. 17), though it is deeply so in one American species, which may belong to this genus, and protuberant in others. In all the four species which we definitely refer to it, the summit is exceedingly small and contracted (Pl. III. fig. 1; Pl. VI. fig. 16; Pl. VIII. fig. 9; Pl. XVI. fig. 12).

The relative proportions of the radial and deltoid plates of *Schizoblastus* are extremely variable, just as in *Granatocrinus*. The radials of *S. melonoides* and *S. Bailii* are very long, and form the greater part of the calyx (Pl. VI. fig. 15; Pl. XVI. fig. 13), just as in *Granatocrinus Norwoodi* (Pl. II. figs. 32–35; Pl. VII. fig. 6), while the deltoids are proportionately small. On the other hand in *Schizoblastus Sayi* and in *S. Rofei* (Pl. VIII. fig. 10) almost the whole of the calyx is formed by the deltoids, and the radials only enclose the distal ends of the ambulacra just as in *Elœacrinus* and in *Granatocrinus Derbiensis* (Pl. II. fig. 46; Pl. IX. figs. 1–4, 6).

The spiracles of *Schizoblastus* are minute slit-like openings which are chiefly formed by lateral notches in the proximal ends of the deltoids. In the type species (*S. Sayi*) they are some little way from the peristome, and the lancet-plate, with the side plates resting upon it, comes up well between the spiracles (Pl. III. fig. 3); but in *S. melonoides*, *S. Rofei*, and *S. Bailii* the spiracles are closer to the peristome, and not so markedly separated by the lancet-plate, as the ambulacrum becomes distinctly narrower between the spiracles (Pl. VI. fig. 16; Pl. VIII. fig. 9; Pl. XVI. fig. 12); while the portion of the deltoid which intervenes between the two spiracles of each interradius is much smaller than in *S. Sayi* (Pl. III. figs. 1–3). In the two Irish species (Pl. VIII. fig. 9; Pl. XVI. fig. 12) there is a compound anal spiracle in the posterior interradius just as in *Cryptoblastus* (Pl. VII. fig. 14); and we have sometimes thought that the same was perhaps the case in *S. melonoides*; but the condition of our specimens does not enable us to satisfactorily decide this point. In *S. Sayi*, however, the central end of the posterior deltoid is considerably enlarged and raised into a sort of projecting hood, which not only covers the anal opening, but also extends outwards over the spiracles at its sides. These are only separated from the anus by two thin partitions, such as Roemer[1] found in the anal spiracle of *Pentremites Godoni*; and if the hood of the posterior deltoid in *S. Sayi* were only a little more arched, it would convert the triple opening into an anal spiracle like that of *Pentremites*.

We do not know much about the hydrospires of *Schizoblastus*. In the Irish *S. Rofei* there is only one sac on each side of the ambulacrum (Pl. XVII. fig. 2), just as in the British species of *Granatocrinus* (figs. 3–7); but in *S. Sayi* they are much more complex, with four folds on each side, which lie very obliquely beneath the ambulacrum and open above into an unusually large hydrospire-canal (fig. 1). The lancet-plate of this type is pierced by three canals like that of *Metablastus*

[1] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. 1, t. 1. f. 2, 3.

lineatus (Pl. XVII. fig. 18), a peculiarity which we have not noticed in any other Blastoid. *S. Sayi* is further remarkable for having as many as eighty side plates which leave a considerable portion of the lancet-plate uncovered in the middle line of the ambulacrum (Pl. III. fig. 3). *S. melonoides* has about fifty, and *S. Rofei* from twenty to thirty, which approach one another rather closely (Pl. VIII. fig. 11). This is the only species in which we have distinctly seen the outer side plates.

Species. The number of species which we can refer to *Schizoblastus* is smaller now than when we first defined the genus; for a personal acquaintance with some of the American species which we formerly only knew from figures and descriptions has shown us that they belong to other generic types.

The species of *Schizoblastus* now recognized by us are as follows:—

Schizoblastus Bailii, sp. nov. Carboniferous Limestone; Ireland.

Granatocrinus melonoides, M. & W. Burlington Limestone, Subcarboniferous; Iowa.

Granatocrinus Rofei, E. & C. Carboniferous Limestone; Ireland.

Pentremites Sayi, O. & S. Burlington Limestone, Subcarboniferous; Iowa.

In addition to these, any one of the following species may be a *Schizoblastus*, though we suspect that some of them would be more properly classed with *Cryptoblastus* or *Mesoblastus*.

Granatocrinus granulosus, M. & W. Keokuk Group, Subcarboniferous; Illinois and Indiana.

Granatocrinus lotoblastus, White. Burlington Group?, Subcarboniferous; Arizona.

Granatocrinus neglectus, M. & W. Burlington Group, Subcarboniferous; Iowa.

Pentremites Missouriensis, Shumard. Chemung Group, Upper Devonian [1]; Missouri.

Pentremites Potteri, Hambach [2]. Burlington Group, Subcarboniferous; Iowa.

Granatocrinus projectus, M. & W. Burlington Group, Subcarboniferous; Iowa.

Pentremites Sampsoni, Hambach. Kinderhook Group, Subcarboniferous; Missouri.

Granatocrinus Shumardi, M. & W. Burlington Group, Subcarboniferous; Iowa.

Distribution. The two Irish species of *Schizoblastus* both occur in the Carboniferous Limestone; while *S. melonoides* and *S. Sayi* are limited to the Burlington Group in the Mississippi Valley Series of the American Subcarboniferous. These

[1] According to S. A. Miller this species belongs to the middle or upper part of the Subcarboniferous.

[2] We do not think that this species is anything more than a small form of *S. Sayi*.

would be the earliest species of the genus, unless the *Pentremites Sampsoni* of Hambach from the underlying Chouteau Limestone, or Shumard's *P. Missouriensis* should prove to be a *Schizoblastus*. The latter was referred by Shumard to the Chemung Group of the Upper Devonian; but Messrs. Meek & Worthen have given reasons for thinking that the beds in Missouri, which Shumard regarded as Devonian, are really of Subcarboniferous age, so that it is extremely doubtful whether *Schizoblastus* can be regarded as a Devonian genus. We know of no species of it above the Burlington Limestone, with the possible exception of *Granatocrinus granulosus*, M. and W., which occurs in the Keokuk Limestone of Indiana and Illinois.

Type. Pentremites Sayi, Shumard.

SCHIZOBLASTUS SAYI, *Shumard*, sp.
(Pl. III. figs. 1–3; Pl. VI. fig. 18; Pl. X. fig. 17; Pl. XVII. fig. 1.)

Pentremites Sayi, Shumard, in Swallow's 1st & 2nd Ann. Report Geol. Survey Missouri, 1855, pt. 2, p. 185, t. B. f. 1, *a–d*.

Granatocrinus Sayi, Shumard, Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 376.

Granatocrinus Sayi, Meek & Worthen, Proc. Acad. Nat. Sci. Philad. 1869, p. 84.

Pentremites Potteri, Hambach, Trans. St. Louis Acad. Sci. 1880, vol. iv. no. 1, p. 156, t. B. f. 4.

Granatocrinus Sayi, Wachsmuth & Springer, Proc. Acad. Nat. Sci. Philad. 1881, t. xix. f. 3.

Schizoblastus Sayi, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 246.

Sp. Char. Calyx subglobose or occasionally somewhat ovoidal; summit flat, or a little concave, and constricted like the base, which presents almost a plane surface, the calyx resting conjointly on the basal plates and radial lips, or sometimes on the latter only; section circular, or slightly pentagonal, the interradial area not divided by deep grooves; periphery equatorial. Basal plates small, flattish, sometimes a little concave, or slightly protuberant, but when so, hardly extending below the level of the lips, and only very slightly perceptible in a side view; basiradial sutures faintly marked. Radial plates quite short, wider than long, forming only about a fourth of the calyx; bodies reduced to a minimum; limbs short and broad, almost flat-sided, or even a little concave; sinuses moderately broad, with erect margins; lips prominent, forming a quinquepod on which the calyx rests; interradial sutures in slight depressions. Deltoid plates very large and long, elongately rhombic and forming quite three fourths the entire length of the calyx, thicker than the radials, and deeply pitted at their central ends; the sides of each plate are obtusely rounded, but the eminences thus formed become narrower towards the base, and leave between them a central triangular depression, which is traversed in the middle line by an obtuse ridge originating behind the depression of the constricted apex; radio-deltoid sutures obliquely arched, and usually deeply depressed. Ambulacra nearly parallel-

sided, on a level with the general surface of the calyx; lancet-plates partially exposed throughout nearly their entire length, and perforated by three canals, arranged in a triangle; ambulacral groove broad and shallow, side plates about eighty[1], transversely wedge-shaped; outer side plates small and apparently triangular. Hydrospire-tubes four on each side, much convoluted; hydrospire-canals large and expanded below. Spiracles ten, small linear slits, notching the edges of the deltoids; posterior spiracles not confluent with the anus, but protected like it by the hood-like central end of the anal deltoid. Mouth small; summit-plates minute and pentagonal. Ornament of the radial plates consists of strong festoon-like granular ridges, parallel to the outline of the plates; the obtuse sides and central ridge of the deltoids are also granular, and the surface contiguous to and parallel with the radio-deltoid sutures bears several V-shaped obtuse ridges.

Remarks. *Schizoblastus Sayi* is readily distinguished from *S. melonoides* (Pl. VI. fig. 16), and from all the doubtful American species in the list which we have given above—with the exception of *Pentremites Potteri*, Hambach—by the very large size of its deltoid plates, which form almost the whole of the calyx, as in *Elæacrinus* (Pl. II. fig. 46). In this respect, however, it resembles the Irish *Schizoblastus Rofei* (Pl. VIII. figs. 9, 10); but this type has a simple anal spiracle, with nothing like the great hood projecting above the three openings which is so characteristic of *S. Sayi*. There seems to be something of the kind in *Granatocrinus neglectus*, M. & W., which has much smaller deltoids than *S. Sayi* and a protuberant base, but in the absence of specimens we cannot say whether it is a *Schizoblastus* or a *Cryptoblastus*.

According to Shumard, there are about eighty side plates in the ambulacrum of *S. Sayi*, but we have not been able to count more than fifty on each side.

The shape of the calyx seems to vary a good deal, two varieties being clearly distinguishable. One is almost globose, and is not unlike some forms of *Granatocrinus orbicularis* (Pl. IX. fig. 11); while the other is more elongated, and resembles one variety of *G. ellipticus* (Pl. VIII. fig. 19). A similar variation occurs in *G. Norwoodi* (Pl. II. figs. 32–35).

Schizoblastus Sayi is of interest as being one of the first species which were found to have the peristome covered by summit-plates. Shumard[2] gave a good figure illustrating this point, and another has since been published by Wachsmuth and Springer[3], while it is also shown in our Pl. III. figs. 2, 3. Hambach[4], however, altogether

[1] *Fide* Shumard.

[2] "Palæontology" in Swallow's First and Second Ann. Report Geol. Survey, Missouri, 1855, pl. B, fig. 1 *c*.

[3] 'Revision of the Palæocrinoidea,' Part II. 1881, pl. xix. fig. 3. There is an unfortunate error in this figure, the deltoids being represented as small plates within the circle of spiracles. Hambach has made use of this as an argument against the existence of the summit-plates, which are also represented in the figure.

[4] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, p. 540.

denies the existence of these summit-plates, and has given various explanations of them, which we have already discussed on pp. 66–69.

He has further described, under the name of *Pentremites Potteri*[1], a fossil which appears to us to be nothing but a small variety of *Schizoblastus Sayi*. Almost every character to which an intelligible reference is made in the specific diagnosis of *P. Potteri* is mentioned in that of *S. Sayi* previously given by Shumard, and is to be found in one or other of the different varieties of this species. The only difference between the two types, according to Hambach, is that *P. Potteri* "is generally smaller, ... the pelvis is not concave, the fork-pieces not arched at the junction of the deltoid piece, and this latter is not elevated and ornamented with transverse striæ, but depressed and granulated." Now, in the first place, we have before us specimens of *S. Sayi* in which the base is respectively a little concave, almost flat, or slightly protuberant. The radio-deltoid suture is more or less distinctly arched in all of them, and it is represented as arched in Hambach's own figure of *P. Potteri*, although he makes a positive statement to the contrary. His description of the deltoids of *P. Potteri* corresponds exactly to the condition of these plates in *S. Sayi*; and neither Shumard nor any later writer has described the deltoids of this type as being "elevated and ornamented by transverse striæ."

Hambach's description of the spiracles of *P. Potteri* appears to us to be either unintelligible or incorrect. It runs as follows:—"Ovo-spiracle apertures and anus very small, and kept separate by the broad deltoid pieces; they are surrounded by the zigzag plicated integument in this as well as in other species." But if the two slit-like spiracles of each interradius are kept separate by the broad deltoid pieces, how can they be "surrounded by the zigzag plicated integument"? This structure is elsewhere described by Hambach as covering the whole ambulacral field; but unless it also extends on to the "broad deltoid pieces, how can it "surround" the slit-like spiracles at their sides? As a matter of fact, the appearance described by Hambach under this name is merely the crenulation of the ambulacral groove and of its lateral branches, as we have already explained on pp. 58, 59; and as it does not occur at all on the deltoid side of the slit-like spiracles, it can hardly be said to "surround" them, either in *Schizoblastus Sayi* (Pl. III. figs. 1–3) or in other species.

Localities and Horizon. Burlington, Iowa; Missouri: Upper Burlington Limestone, Subcarboniferous.

SCHIZOBLASTUS MELONOIDES, *Meek & Worthen*, sp.
(Pl. VI. figs. 15, 16.)

Granatocrinus melonoides, Meek & Worthen, Proc. Acad. Nat. Sci. Philad. 1869, p. 88.

[1] Trans. St. Louis Acad. Sci. 1880, vol. iv. no. 1, p. 156, pl. B. fig. 4.

Granatocrinus melonoides, Meek & Worthen, Report Geol. Survey Illinois, 1873, vol. v. p. 468, t. 9. fig. 1.

Schizoblastus melonoides, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 246.

Sp. Char. Calyx subglobose, melon-shaped; summit convex and much restricted; peristome concave; base small, contracted, and more or less flattened; section decagonal; periphery nearly equatorial. Basal plates very small, confined to the central flattened portion of the base. Radial plates long, four fifths the length of the calyx; bodies very small, turned in at the base; limbs long, obliquely truncated at the upper ends, margins subparallel. Each limb has a broad sulcus or depression next the edge of the sinus, extending the whole length of the plate, the surface along the interradial suture swelling into a broad, rounded ridge tapering upwards and downwards; lips prominent, forming supports for the calyx when in position; sinuses narrow, sublinear, and very long, with parallel sides; interradial sutures in depressions between the lateral ridges of adjacent limbs. Deltoid plates small, unequally rhombic, concave, and constricted at their central ends. Ambulacra sub linear, depressed below the edges of the sinuses at their proximal ends, but raised above them towards their apices; lancet-plates mostly concealed; side plates fifty or more. Hydrospires unknown. Spiracles (ten) very small, linear or slit-like, quite apical, and formed as in *S. Sayi*. Column round. Ornament minutely granular, the granules arranged in more or less wavy lines, parallel to the margins of the plates.

Remarks. The description of this species by Messrs. Meek and Worthen is clear and comprehensive, as all their descriptions are; but their figure fails to show the broad obtuse interradial ridges which are so characteristic of it, and assist in giving to it a roughly decagonal outline in cross section. The interradial sutures are sometimes placed on these ridges; but they are generally depressed between the ridges of contiguous radials. In well-preserved specimens the surface is minutely granular, but the linear arrangement of the granules becomes apparent on weathering.

Messrs. Meek and Worthen have very justly compared this species with *S. Sayi* and with *Cryptoblastus melo.* It is at once distinguished from the former and from *S. Rofei* (Pl. VIII. figs. 9, 10) by the different proportions of its radial plates. In *Cryptoblastus melo* these plates are very long, like those of *S. melonoides*, but there is no trace of the vertical rounded ridges which are seen on the plates of the latter species, and give it so very marked an appearance. Again, in *C. melo* the basal plates are concealed in a central concavity, but in *S. melonoides* they are quite flat, or perhaps very slightly apparent in a side view; while there are hydrospire-pores along the edges of the deltoids, which is not the case in *Cryptoblastus*.

Locality and Horizon. Burlington, Iowa: Upper Burlington Limestone, Subcarboniferous.

SCHIZOBLASTUS ROFEI, *E. & C.*

(Pl. VI. fig. 17; Pl. VIII. figs. 9–11; Pl. XVII. fig. 2.)

Granatocrinus Rofei, E. & C. (MS.), Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 239.

Sp. Char. Calyx small, elliptical, subglobose; base truncate, more or less flattened, with a small and moderately deep central concavity; section obtusely pentagonal, with the angles of the pentagon truncated and the sides slightly concave; periphery nearly equatorial. Basal plates very small, chiefly confined to the basal concavity, but extending slightly beyond it. Radial plates very small and short, but not wholly visible in a basal view; limbs very short, and horizontally truncated above; sinuses relatively wide, parallel-sided for two thirds of their course; radial portions very short, and merely receiving the apices of the ambulacra, their margins prominent; radio-deltoid sutures horizontal, faintly marked as a rule; lips small and thickened, but not very prominent. Deltoid plates large, long, and triangular, concave, with a well-marked granular median longitudinal ridge; apices enlarged; lateral margins thickened and strongly granular. Ambulacra not projecting above the edges of the sinuses; lancet-plate but slightly exposed; side plates relatively large, twenty to thirty, almost transversely pyriform in shape; outer side plates very minute; pores large, excavated in the sides of the sinuses. One hydrospire-tube. Spiracles very small, appearing as eight elongated slits at the sides of the deltoids; the posterior pair confluent with the anus, which is large and oval. Ornament consists of coarse strong granules, few in number, and arranged in rows, those along the margins of the sinuses more numerous and closer together; apices of the deltoids devoid of ornament.

Remarks. The collection contains numerous examples of this little species, which we believe to be quite undescribed. We have previously referred to it as an aberrant species of *Granatocrinus*[1]; but an examination of some better-preserved material than was available when our figure of the summit was drawn (Pl. VIII. fig. 9) has led us to transfer it to *Schizoblastus*, and we have been confirmed in this determination by the discovery of another species of the genus also from the Carboniferous Limestone of Ireland (Pl. XVI. figs. 12, 13). The latter type has been kindly lent to us for comparison by Mr. W. H. Baily, F.G.S., of the Irish Geological Survey, to whom we have dedicated the species. The small size of its deltoid plates readily distinguishes it from *S. Rofei* (Pl. VIII. fig. 10), which in this respect resembles the type of the genus, the American *S. Sayi*. But in both the Irish species the posterior spiracles are confluent with the anus, and this is not the case in *S. Sayi*, which has all three openings protected by a strongly arched hood.

The coarsely granular character of the calyx is a very marked feature in *S. Rofei*, a point in which it resembles some forms of *Granatocrinus ellipticus* (Pl. VI. fig. 21), and the other British species of *Granatocrinus* (Pl. IX. figs. 8–10; Pl. X. figs. 5, 7–9,

[1] Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 239.

16). It further resembles these types in having but one hydrospire-tube on each side of an ambulacrum (Pl. XVII. figs. 2–7), although *S. Sayi*, the type of the genus, has a much more complex hydrospire-apparatus (fig. 1).

Locality and Horizon. Foot of Beneachlin, Florence Court, Fermanagh: Carboniferous Limestone. (Presented by the Right Hon. the Earl of Enniskillen, D.C.L., F.R.S.)

Genus CRYPTOBLASTUS, gen. nov.

Pentatrematites Elliptici (pars), Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 391.
New Genus (pars), Owen & Shumard, Wisconsin, Iowa, and Minnesota Geol. Report, 1852, p. 591.
Subgenus of Pentremites, Meek & Worthen, Proc. Acad. Nat. Sci. Philad. 1861, p. 142.
Elæacrinus (pars), Shumard, Trans. St. Louis Acad. Sci. 1863, vol. ii. no. 1, p. 111.
Granatocrinus (pars), Shumard, *ibid.* 1865, vol. ii. no. 2, p. 375.
Granatocrinus (pars), Meek & Worthen, Report Geol. Survey Illinois, 1866, vol. ii. p. 274.
Schizoblastus (pars), E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 243.

Gen. Char. Calyx subglobose, with a flattened or slightly hollowed base. Basal plates small and inconspicuous. Radial plates long and deeply incised. Deltoid plates relatively small and unequally rhombic, the four anterior plates notched by the spiracles near their central ends, and the posterior one pierced by a large anal spiracle. Lancet-plate separated from the radials by an hydrospire-plate, which does not extend above the radio-deltoid suture; but above this line the lancet-plate meets the deltoids without leaving any hydrospire-pores.

History. The species which we have taken as the type of this genus (*Pentremites melo*, O. & S.) was first described, together with *Pentremites Norwoodi*, by Owen and Shumard [1], who regarded it as probable that these two species would together "constitute a new genus" of Blastoids. They did not, however, propose any new name for the purpose; and this step was not taken till 1862, when Hall [2] suggested the separation of these species from *Pentremites*, under the MS. name *Granatocrinus*, which had been employed by Troost for a Blastoid resembling the two species of Owen and Shumard in the general external characters of the calyx. He pointed out that they differ from *Elæacrinus* (or, as he called it, *Nucleocrinus*) in not having the anal interradius conspicuously different from its fellows. About the same time, however, Shumard [3] referred to *Elæacrinus* all the species which Hall was proposing to place under *Granatocrinus*; and, so far as *Pentremites melo* and *P. Sayi* were concerned, there can be no doubt that the arrangement he proposed was better than that suggested by Hall. *P. Norwoodi* and its European allies, which Shumard proposed

[1] Wisconsin, Iowa, and Minnesota Geol. Report, 1852, p. 591.
[2] Fifteenth Ann. Rep. New York State Cab. Nat. Hist. 1862, p. 146.
[3] Trans. St. Louis Acad. Sci. 1863, vol. ii. no. 1, p. 112.

to place under *Elæacrinus*, belong, however, to an altogether different type of Blastoid structure. A few years later, however, he adopted Hall's suggestion [1]; but the genus *Granatocrinus* was never properly defined till 1866, when some valuable remarks upon it were published by Messrs. Meek and Worthen [2]. They included in it, not only *P. Sayi*, which is the type of our *Schizoblastus*, but also *P. Norwoodi* and *P. melo*; and they described the spiracles of these two types as "piercing directly through them (deltoid plates), so that each pair appears externally as a single opening, though they divide into two distinct canals before passing entirely through the plates." This is indeed true of *P. Norwoodi*, as seen in our Pl. VII. figs. 5–8, but it is not the case in *P. melo* (figs. 14, 15); and it was perhaps the knowledge of this fact which led Meek and Worthen to remark in a footnote:—"In worn or weathered specimens of *G. melo* and *G. Norwoodi* these little interradial pieces have been so much eroded as to expose each pair of these openings entirely distinct, when they were really united, and appeared as a single opening externally, before wearing." It is quite true that a double spiracular opening is occasionally visible in *G. Norwoodi* (Pl. VII. fig. 12), but it is the normal condition of *G. melo* (figs. 14, 15). In fact, Meek and Worthen had already recognized this condition in 1861 [3], before Hall's reference of *P. melo* to *Granatocrinus*. Speaking of *P. melo* and of its ally *P. projectus*, they said:—"Both these forms differ from the typical species of the genus *Pentremites* in having each pair of ovarian openings distinctly separated, instead of closely united, with merely a thin septum between. In this character, as well as in form and the prolongation of the pseudo-ambulacral areas, they agree with the genus *Nucleocrinus* of Conrad (=*Eleacrinus*, Roemer), from which they differ in having the anal and oral openings distinct, as in the true *Pentremites*. They constitute a subgenus of *Pentremites*, occupying a position between the typical forms of that genus and *Nucleocrinus*."

In these valuable remarks we entirely concur [4], and we much regret that the authors did not take any further steps to establish a new subgeneric type on the characters which they so clearly specified. They would thus have anticipated Hall's transfer of *P. melo* and *P. Norwoodi* to *Granatocrinus*, a step in which they afterwards concurred; and, as we have already seen, they then regarded the presence of eight spiracles in *P. melo*, besides that in the anal interradius, as due to the effects of much erosion.

Remarks. In reality, however, it is a perfectly natural condition (Pl. VII. figs. 14, 15), and the spiracles do not lead into any canals "passing entirely through the (deltoid) plates," as stated by Meek and Worthen, although this actually is the case

[1] Trans. St. Louis Acad. Sci. 1863, vol. ii. no. 2, p. 375.

[2] Report Geol. Survey Illinois, 1866, vol. ii. p. 274.

[3] Proc. Acad. Nat. Sci. Philad. 1861, p. 142.

[4] Except, of course, as regards the mouth of *Elæacrinus*.

in *G. Norwoodi* (Pl. VII. figs. 7–9). But herein lies the whole difference between the two species. In the latter type the hydrospire-canals at the sides of the radial sinus enter the substance of the deltoids at the sutures between them and the radials, the two within each deltoid converging on the spiracle at its central end. There are, consequently, no hydrospire-pores along the ambulacral edges of the deltoids, as there is no canal beneath the lancet-plate into which they could lead.

In the so-called *Pentremites melo*, however, there is an altogether different arrangement (Pl. VII. fig. 15). As in *Granatocrinus* (Pl. X. figs. 11, 12), there is an hydrospire-plate between the lancet-plate and the walls of the radial sinus; but this plate does not extend upwards above the radio-deltoid suture, so that the lancet-plate comes into direct and continuous contact with the deltoids. The proximal ends of these last, and also, though in a less degree, the lancet-plate itself, are notched by the spiracles; and the hydrospire-canal into which each spiracle leads is concealed beneath the lancet-plate until it opens to the exterior through the hydrospire-pores along the ambulacral edges of the radials. It was this character which suggested to us the name *Cryptoblastus*, when we found it necessary to separate *Pentremites melo* from the genus *Schizoblastus*, in which we formerly placed it. The deltoids of *Schizoblastus* are of variable size, as they form the greater part of the calyx in *S. Rofei* (Pl. VIII. fig. 10), while in *S. melonoides* and *S. Bailii* (Pl. VI. figs. 15, 16; Pl. XVI. figs. 12, 13) they are as small as in *Cryptoblastus melo* (Pl. VII. figs. 14, 15). But in both of these species there are hydrospire-pores at the sides of the deltoids, and we have been unable to determine the presence of an hydrospire-plate either in these two species or in *S. Rofei* and *S. Sayi*. In one American species, however, which we formerly referred to *Schizoblastus* on account of its having divided spiracles like *S. Sayi*, we have found essentially the same morphological characters as in *Cryptoblastus melo*. We refer to *Granatocrinus pisum*, M. & W., specimens of which have been recently received by one of us from an American correspondent; and they show the same absence of pores along the sides of the small deltoids, and the presence of an hydrospire-plate between radial and lancet-plate as we have noted in *Cryptoblastus melo* (Pl. VII. fig. 15). As in this species too, the posterior spiracles are confluent with the anus, which is not the case in *Schizoblastus Sayi*. The same is the case in *Elæacrinus Kirkwoodensis*, which was described by Shumard [1] as being "nearly allied to *E.* (*Pentremites*) *melo*," and as having long radials, which implies correspondingly small deltoids.

There are various other American species which have been described under *Granatocrinus*, and have been said to be more or less like *G. melo*. But we do not think that any of them can be referred to *Cryptoblastus*. Thus, for example, *G. melonoides* (Pl. VI. figs. 15, 16) appears to us to be a *Schizoblastus*, while *G. lotoblastus*, White [2],

[1] Trans. St. Louis Acad. Sci. 1863, vol. ii. no. 1, p. 113.

[2] Report Wheeler's Survey West of 100th Meridian, 1875, vol. iv. p. 80.

with its very short radials, may be either a *Granatocrinus* like *G. Derbiensis* (Pl. IX. figs. 1, 6), a *Schizoblastus* like *S. Sayi*, or an *Elæacrinus*. But we cannot attempt to give it a generic name in the absence of any detailed knowledge of its summit-structure. *G. projectus*, on the other hand, which was formerly regarded by Meek and Worthen only as a variety of *G. melo* [1], is not improbably a *Cryptoblastus*. The anal deltoid is more prominent than the others, which are comparatively small, while the base is also slightly protuberant. These characters are more pronounced in *G. neglectus*, M. & W., but it has rather larger deltoids [2], and we cannot make out from Meek and Worthen's figure whether or not the posterior spiracles are confluent with the anus.

We recognize the following species of *Cryptoblastus*:—

? *Elæacrinus Kirkwoodensis*, Shumard. St. Louis Limestone, Subcarboniferous; Missouri.

Pentremites melo, O. & S. Burlington Group, Subcarboniferous; Iowa, Missouri, Illinois.

? *Pentremites melo*, var. *projectus*, M. & W., var. Burlington Group, Subcarboniferous; Iowa.

Granatocrinus pisum, M. & W. Burlington Group, Subcarboniferous; Iowa, Missouri.

Distribution. The genus is exclusively confined to the Subcarboniferous of America, the last three species in the above list belonging to the Burlington Limestone, while Shumard obtained the first one from the St. Louis Limestone.

Type. Pentremites melo, Owen & Shumard.

CRYPTOBLASTUS MELO, *Owen & Shumard*, sp.

(Pl. VII. figs. 14, 15.)

Pentremites melo, Owen & Shumard, Journ. Acad. Nat. Sci. Philad. 1850, vol. ii. pt. 1, p. 65, t. 17. f. 4 *a–c*.

Pentremites melo, Owen & Shumard, Wisconsin, Iowa, and Minnesota Geol. Report, 1852, p. 592, t. 5 A. f. 14, *a–c*.

Elæacrinus melo, Shumard, Trans. St. Louis Acad. Sci. 1863, vol. ii. no. 1, p. 112.

Granatocrinus melo, Shumard, *ibid.* 1865, vol. ii. no. 2, p. 375.

Granatocrinus melo, Meek & Worthen, Proc. Acad. Nat. Sci. Philad. 1869, p. 84.

Schizoblastus melo, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 246.

Sp. Char. Calyx subglobose, or elongate-globular, resting on the radial lips; summit flat, and wider than the base; peristome concave; base more or less

[1] Proc. Acad. Nat. Sci. Philad. 1861, p. 142.

[2] Report Geol. Survey Illinois, 1873, p. 471, pl. 9. fig. 3.

contracted, and concave centrally; section roughly decagonal, the interradial areas divided by deep grooves; periphery almost equatorial, or perhaps a little nearer the summit. Basal plates small, quite hidden in a side view; basiradial sutures usually plainly visible. Radial plates more or less elliptical, gently convex; bodies reduced to a minimum, and either on a level with the outer edges of the basal plates, or projecting below them; limbs forming four fifths of the calyx, horizontally truncated above, narrow, and convex, and the lateral margins almost vertical; sinuses extending nearly the whole length of the calyx, and bounded almost entirely by the radial plates; lips projecting and acting as supports, on which the calyx rests when in its natural position; interradial sutures in deep but narrow depressions. Deltoid plates small and triangular, with broad bases, constricted at their proximal ends, and projecting above the summit. Ambulacra convex or angular, sublinear, inserted in the sinuses more deeply at their proximal than at their distal ends; ambulacral groove deeply impressed in the lancet-plate, and forming the only part of the latter which is exposed; side plates elongated, subhexagonal[1], from forty-five to fifty in number, usually concealing the hydrospire-plate. Two hydrospire-folds on each side of an ambulacrum; spiracles eight, oval, chiefly excavated in the lateral margins of the deltoids, having each of their inner edges obliquely raised and thickened into a small border. Mouth moderately large, covered by minute angular plates. Anus transversely oval, bounded distally by a boss or node, which is more prominent than on the other deltoids. Ornament consisting of granules roughly arranged in longitudinal rows.

Remarks. This is a much larger form than either of the other species which we refer to *Cryptoblastus*, except perhaps *C.? projectus*; while it is also readily distinguished by its sunken ambulacra and the deeply furrowed interradial sutures (Pl. VII. fig. 14).

We have made no sections of the hydrospires of this species, but there are some examples of it in Mr. Wachsmuth's collection which show that it has two folds on each side of the ambulacrum just like *G. Norwoodi* (Pl. VII. figs. 1, 2). This has already been mentioned by Meek and Worthen[2], who have also seen specimens with the peristome covered by a vault of small plates which extends downwards over the ambulacral grooves.

Cryptoblastus melo is taken by Hambach[3] as the type of his second division of the genus *Pentremites*, which has "ten distinctly visible openings," *i. e.* spiracles. He associates with it four other species, viz.—*P. Sayi*, Shumard, *P. Roemeri*, Shumard, *P. Burlingtonensis*, Meek & Worthen, and *P. crenulatus*, Roemer. Some of these species, however, do not answer to his description. There are ten spiracles in *Schizoblastus Sayi* (Pl. III. figs. 1–3) and also in that form of *Pentremites Roemeri* which Shumard subsequently called *Granatocrinus Missouriensis*[4]; but there are

[1] Owen and Shumard.

[2] Proc. Acad. Nat. Sci. Philad. 1869, p. 84.

[3] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, p. 545.

[4] Swallow's 1st & 2nd Ann. Report Geol. Survey Missouri, 1855, pt. 2, pl. B. fig. 2*d*; & Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 375.

only eight on the summit of *P. Burlingtonensis*, as the posterior pair are confluent with the anus, so that there are not ten, but only nine, "distinctly visible openings" besides the mouth. We doubt whether Hambach has ever seen *P. crenulatus*, and suspect that his knowledge of its summit is confined to Roemer's figure [1]. But even this does not show ten spiracles. There is a large undivided anal spiracle, and four others which are partially divided, as in our Pl. VI. fig. 8; but we think that even Hambach would hesitate before he spoke of "ten distinctly visible openings" in the specimen represented on Pl. IV. fig. 1.

On the other hand, there are really nine openings in his type species *Pentremites melo* (Pl. VII. fig. 14), viz. four pairs of ordinary spiracles and one anal spiracle. But the diagram which Hambach gives of the summit of this species shows ten openings besides the anus, whereas there are really only eight. He has inserted a pair of spiracles in the posterior interradius which have no existence in fact (Pl. VII. fig. 14), but are necessary to his system of classification. The five species which he names as belonging to his second division of the genus *Pentremites* represent, in our view, four different generic types—viz. *Cryptoblastus*, *Schizoblastus*, *Mesoblastus*, and *Pentremites*, and we believe that those palæontologists who have read the preceding chapters will not think our system of classification so "impracticable" as it is said to be by Hambach.

Localities and Horizon. Burlington, Iowa; Hannibal and St. Louis Co., Missouri; near Monmouth, Illinois: Lower Burlington Limestone, Subcarboniferous.

Genus ACENTROTREMITES, *E. & C.*, 1883.

Mitra, Cumberland (pars), Reliquiæ Conservatæ, 1826, p. 31.
Acentrotremites, E. & C., Ann. & Mag. Nat. Hist. 1883, vol. xi. p. 232.

Gen. Char. Calyx elliptical, with a broad pentagonal base largely formed by the radials, which also take up three fourths of its height. Deltoids unequally rhombic, each notched by two spiracles at the ends of the radio-deltoid suture. Anal opening situated close to the peristome in the posterior deltoid.

Remarks. We established this genus in 1883 for a very singular form which, in some respects, is intermediate between *Cryptoblastus* and *Schizoblastus*. It resembles the type of the latter genus (*S. Sayi*) in the presence of distinct spiracles in the posterior interradius. But the anal opening, instead of being between the spiracles as in that species, or farther from the peristome as in *S. Missouriensis*, is situated at the central end of its deltoid quite close to the peristome (Pl. XIII. fig. 19), while the ten spiracles notch the outer ends of the deltoids where the radio-deltoid sutures meet the ambulacra. There are, therefore, no hydrospire-pores along the ambulacral edges of the deltoids. This is also the case in *Cryptoblastus* (Pl. VII. fig. 15), but it

[1] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. Taf. iv. f. 15 c.

is due to the concealing of the hydrospire-canal by the lancet-plate, which comes into direct contact with the deltoids, except at the spiracles; whereas in *Acentrotremites* the hydrospire-canal opens externally through the spiracles at the aboral ends of the deltoids, and is not therefore continued onwards along their ambulacral edges as it is in *Cryptoblastus.* At any rate, this is what we should infer from the condition of the specimen represented in Pl. XIII. figs. 18, 19, which seems to indicate that the proximal ends of the hydrospire-tubes are situated at a point much lower in the calyx than is generally the case in the Blastoidea. It is quite possible, however, that the hydrospire-slits may extend upwards on to the deltoids within the ring of spiracles without having any communication with the exterior through pores at the sides of the ambulacra. There are various other Blastoids, however, in which the hydrospire-slits are practically limited to the radials, scarcely any portions of them extending upwards on to the deltoids, e. g. *Granatocrinus Norwoodi*, so far as can be judged from the condition of the internal casts (Pl. VII. figs. 7–9), and *Orophocrinus* (Pl. XV. figs. 4, 10).

The last-mentioned genus resembles *Acentrotremites* in having a distinct anal opening and ten groups of hydrospires. The enlarged proximal ends of the clefts by which these open externally, represent the spiracles of *Acentrotremites*; and in the best-known species (*O. stelliformis*, Pl. XI. fig. 9) they occupy very much the same position as their homologues do in that genus, viz. at the junction of the radio-deltoid sutures with the ambulacra. But the other characters of *Orophocrinus*, and especially those of the European species, are such as to separate it entirely from *Acentrotremites.* The same may be said of *Metablastus* and *Tricœlocrinus* (Pl. III. figs. 14, 15; Pl. XIX. figs. 15, 16), which also have an anal opening and ten spiracles, while *Elœacrinus* is distinguished by its anal plate.

Species. When we first described *Acentrotremites* from the characters of Cumberland's *Mitra elliptica*, we also referred to this genus a fragmentary specimen from Clitheroe in the Rofe collection (Pl. IV. fig. 3). But we have since seen some better-preserved examples of the latter type, and find that it is really a large species of *Mesoblastus*, which we shall describe hereafter as *M. Rofei.*

Distribution. The only known species of *Acentrotremites* is confined to the Carboniferous Limestone of Britain.

Type. Mitra elliptica, Cumberland.

Acentrotremites ellipticus, *Cumberland*, sp.

(Pl. XIII. figs. 17–19.)

Mitra elliptica, Cumb., Reliquiæ Conservatæ, 1826, p. 33, t. B. f. 1–3 (middle group) [non *Pentremites elliptica,* G. B. Sby.].

Sp. Char. Calyx large, tapering upwards; base flat, or very slightly concave; sides

concave below, flattened upwards towards the summit, which is rounded, and sometimes contracted; periphery at or near the margin of the flattened base; section distinctly pentagonal, with the angles at the periphery occupied by the radial lips. Basal plates sunken, not visible, placed within the basal concavity or depression. Radial plates very long, narrowed towards the base, and occupying two planes—one part is horizontal, and assists in forming the base, while the other is more or less at right angles to it, and constitutes the limbs; radial sinus very long and narrow, more than two thirds the length of the entire plate; lips obtuse. Deltoid plates relatively small, and unequally rhombic; the anal deltoid flatter than the others. Ambulacra long and much curved, widest at the level of the radio-deltoid sutures, and gradually narrowing to the prominent apices; lancet-plates completely concealed by the side plates, which are large, very numerous, wider than the lancet-plates, and bent down at a considerable angle on each side of the ambulacra; pores large and very numerous, one hundred and more on each side. Spiracles ovate-oblong, their distal ends resting on the radio-deltoid sutures. Mouth small. Anus oblong and close to the peristome. Column large; columnar facet within a deep basal concavity. Ornament not preserved.

Remarks. The specimen described above is one of the largest of our British Blastoids, measuring 30 mm. in height by 25 mm. across the base. We think that there can be little doubt of its identity with the *Mitra elliptica* of Cumberland, although it differs from his figures in one or two points. He represents the central half of the flattened base of the calyx as occupied by five basal plates, a number which occurs in no known Blastoid; and we cannot help suspecting that this must be erroneous. In our specimen the centre of the base is occupied by a circular concavity, which is filled with calc-spar, the remains of the upper stem-joints (Pl. XIII. fig. 17). The interradial sutures extend downwards as far as this hollow, which probably contains the basals just as in *Elæacrinus* (Pl. II. fig. 45) and in *Granatocrinus ellipticus* (Pl. VIII. fig. 18). But it is relatively smaller than the pentapartite base of Cumberland's figure. Then, again, Cumberland spoke of and represented the interradial sutures as extending right up to the peristome, while there is no trace of spiracles in either of his figures. But as some of his other figures are equally incorrect, *e. g.* those of *Mesoblastus elongatus* (= *Mitra elongata*, Cumb.), we do not attach very much importance to this point.

There is one character of *Acentrotremites ellipticus* about which we are somewhat uncertain. We refer to the existence of an hydrospire-plate. The condition of the ambulacrum figured on Pl. XIII. fig. 19, seems to indicate its presence; but we are by no means satisfied about it, and must leave this point to be worked out when better material is available.

Cumberland gives no locality for his specimen, but described it as consisting of white limestone like *Mitra elongata*, which occurs in Lancashire and Yorkshire, and we conclude, therefore, that his specimen of *M. elliptica*, which seems to have

disappeared, came from the same neighbourhood. The example which we have figured is of a dark red colour, and was found in the Carboniferous Limestone of Somersetshire. There is therefore a possibility that it may be the *Pentremites globosa* of Say, who referred to the type as follows[1]:—"This large and fine species belongs to the Philadelphia Museum. It was brought from England by Mr. Reubens Peale, who understood that it was found in the vicinity of Bath. None of this species, I believe, has yet been found in America." The measurements of Say's specimen are—"Length one inch and one fifth; greatest breadth one inch and three tenths;" and these are not very different from the corresponding measurements of our type. Shumard[2] says of Say's specimen that it "most likely belongs to *Granatocrinus* or *Elæacrinus*," both of them forms which are altogether unlike *Pentremites* proper. *Elæacrinus* has ten spiracles, just like *Acentrotremites*, and this is the chief objection to the suggestion that Say's type belongs to our new genus; for he called it *Pentremites globosa*, and specially mentioned the five summit-openings as characteristic of the genus, of which *P. globosa* was the first species named by him.

Locality and Horizon. Somersetshire: Carboniferous Limestone.

Family *GRANATOBLASTIDÆ*, E. & C., 1886.

Definition. Calyx globular or ovoidal, with flattened or concave base and linear ambulacra. Spiracles five, piercing the deltoids, or ten, grooving their lateral edges.

Remarks. This family is closely allied to the Schizoblastidæ in the general relations of the calyx and of its narrow ambulacra, but differs from all other Blastoids in the summit characters. In the type genus, *Granatocrinus*, there is but one spiracle in each interradius, which pierces the central end of the deltoid, and leads inwards through its substance into two hydrospire-canals, that diverge rapidly, and open into the proximal ends of the hydrospire-sacs at its sides (Pl. VII. figs. 5–9). No other Blastoid presents anything like this relation of the hydrospire-canals to the deltoid plates, with the exception of the recently discovered *Heteroblastus*. In this remarkable type the inner face of each deltoid is marked by two grooves, which lodge the proximal ends of the hydrospire-canals, and have minute external openings at the sides of the ambulacra (Pl. VI. figs. 3, 4). The deltoids are thus distinctly excavated to form the internal connections of the spiracular openings, though by grooves only, not by canals; and these grooves open separately, instead of having a common aperture as in *Granatocrinus*. In abnormal examples of the latter type, however, there may be two openings in the deltoid, as shown in Pl. VII. fig. 12; and if they were a little nearer to the edges of the plate the canals would be reduced to the condition of grooves as in *Heteroblastus*. The partial division of the spiracles of *G. McCoyi* by

[1] Journ. Acad. Nat. Sci. Philad. vol. iv. pt. ii. p. 294.

[2] Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 385.

imperfect septa (Pl. X. fig. 8) is another instance of an approximation to *Heteroblastus*. We have not been able to make out an hydrospire-plate in this genus, though it is well developed in *Granatocrinus* (Pl. VIII. figs. 15, 20; Pl. X. figs. 11, 12, 14).

The differences between the two genera can be thus expressed :—

Five spiracles, piercing the deltoids. An hydrospire-plate.	*Granatocrinus.*
Eight (or ten ?) small spiracles, grooving the edges of the deltoids. No hydrospire-plate.	*Heteroblastus.*

Genus GRANATOCRINUS (*Troost*, 1849; *Hall*, 1862) [emend. *E. & C.*, 1882].

Mitra (pars), Cumberland (non Lamk.), Reliquiæ Conservatæ, 1826, p. 31.
Pentremites, G. B. Sowerby, Zool. Journ. 1825, vol. ii. no. 7, p. 316.
Pentatrematites (pars), G. B. Sowerby, Zool. Journ. 1828, vol. iv. no. 13, p. 89.
Orbitremites, J. E. Gray (MS.), Synop. Contents Brit. Mus. 42nd edit. 1840, p. 63.
Granatocrinites, Troost (MS.), American Journ. Sci. 1849, vol. viii. p. 420.
Granatocrinites, Troost (MS.), Proc. American Assoc. Adv. Sci. for 1850 [1851], p. 62.
Pentatrematites Elliptici (pars), Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 360.
Pentremites (pars), McCoy, Brit. Pal. Foss. 1851, fasc. 1, p. 123.
New Genus (pars), D. D. Owen, Wisconsin, Iowa, and Minnesota Geol. Report, 1852, p. 591 (note).
Pentremites (pars), Dujardin & Hupé, Hist. Nat. Zooph. Échinod. 1862, p. 89.
Granatocrinus (pars), Hall, Fifteenth Ann. Rep. New York State Cab. Nat. Hist. 1862, p. 146.
Elæacrinus (pars), Shumard, Trans. St. Louis Acad. Sci. 1863, vol. ii. no. 1, p. 112.
Granatocrinus (pars), Shumard, Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 375.
Granatocrinus (pars), Meek & Worthen, Report Geol. Survey Illinois, 1866, vol. ii. p. 274.
Granatocrinus, Zittel, Handb. Pal. 1879, Bd. i. Lief. 3, p. 434.
Granatocrinus (pars), E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 236.

Gen. Char. Calyx oval, orbicular, globose, or subglobose; summit convex, frequently contracted, and sometimes depressed; base small, sometimes contracted, with a central concavity of variable depth, seldom flat; section pentagonal, round, or roughly decagonal; interradial areas more or less concave in most of the species, but round or flattened in those having a decagonal section. Basal plates small, not visible in a side view, but usually concealed in the central columnar cavity. Radial plates of variable size, very short, of medium length, or extending more or less the whole height of the calyx, but invariably turned in below to assist in forming the base; sinuses very long and sublinear, extending the whole length of the calyx, which usually rests on the radial lips. Deltoid plates of variable size and form, usually unequally rhombic, but sometimes triangular or arrowhead-shaped, large in some species,

occupying quite half the length of the calyx, in others quite small and confined to the vicinity of the summit; the anal deltoid frequently different in shape and appearance from the others. Ambulacra narrow or sublinear, and nearly parallel-sided, sometimes deeply impressed within the sinuses, always more or less so at their proximal ends; lancet-plates narrow and not filling the sinuses, more or less exposed throughout two thirds of the ambulacra; side plates transversely elongated, but of variable form, from twenty to eighty in number. Outer side plates generally well developed. Hydrospires pendent, usually but a few folds on each side of an ambulacrum, the inner one forming a well-defined hydrospire-plate. Spiracles five, piercing the more or less constricted apices of the deltoid plates as round or oval openings, sometimes rising into short erect tubes, and frequently guarded at their outer margins by nodular thickenings. Posterior spiracle including the anus, and forming a large pyriform opening. Mouth usually small, and covered with minute summit-plates, which rarely exhibit any definite arrangement. Column round. Ornament lineate granular.

History. The origin of the name *Granatocrinus* may be traced back to the year 1849, when Troost designated a new species by the name of *Granatocrinites cidariformis*, but unfortunately neither genus nor species was ever described. We believe that Prof. James Hall was the first to formally use the name *Granatocrinus*, in 1862, but without any precise definition, although his observations may be said to have laid the foundation of our knowledge of the genus as it is now understood. It corresponds to a portion of Cumberland's earlier genus *Mitra*, published in 1826, a name, however, which we are unable to use, from its preoccupation by Lamarck for a genus of Mollusca. We have also little doubt that it was for the British representatives of *Granatocrinus* that Dr. J. E. Gray proposed the name *Orbitremites* as early as 1840, so far as we can judge from the list of species appended to this name by the Messrs. Austin in 1842, in their "Proposed Arrangement of the Crinoidea"[1].

Dr. Troost was not the only writer who appears to have seen the necessity for a generic separation of certain forms from the original type of *Pentremites*, for Drs. Owen and Shumard, commenting in 1852 on their *Pentremites Norwoodi* and *P. melo* (species afterwards placed in *Granatocrinus*), suggested that they would form the type of a new genus.

After Hall, Dr. F. B. Shumard appears to have possessed the clearest views on *Granatocrinus*; for in 1865 he wrote, "The *Granatocrinus* (*Pentremites*) *granulatus*, Roemer, = *G. cidariformis*, Troost, may be regarded as the type of the genus, and *for the present it may be extended*[2], so as to include such species as *Pentremites melo*, and *P. Norwoodi*, and allied forms, though it may become necessary after a while to

[1] Ann. & Mag. Nat. Hist. 1842, vol. x. p. 111. We may remark for the information of our American fellow-workers, and of Mr. Hambach in particular, that Gray's name has nine years' priority over Troost's, but, like it, is only an MS. name. We feel bound, therefore, to adopt *Granatocrinus*, though we think that it should be credited to Prof. James Hall rather than to Dr. Troost. [2] The italics are ours.

remove these from *Granatocrinus*, and group them in a separate subsection under another name"[1]. The first actual description of *Granatocrinus* to appear was that published in 1866 by Messrs. Meek and Worthen, who appended many valuable anatomical details, and discussed the affinities of this type to *Elæacrinus* and to *Pentremites*. Since that date their definition of the genus has been pretty generally accepted, but in 1882 we suggested certain modifications, which will be more advantageously discussed further on.

Remarks. The majority of American palæontologists having agreed to distinguish as a separate genus a series of forms with the general structure of *Pentremites Norwoodi*, O. & S., *P. melo*, O. & S., and *P. Sayi*, Shumard, under the name of *Granatocrinus*, it became necessary to seek a well-defined type. Troost's *G. cidariformis* never became more than an MS. name; and, according to Dr. Shumard, the species is identical with *Pentremites granulatus*, Roemer. The latter unfortunately is equally little known, having been described only from an internal cast, no mention being made of the structure of the summit. A knowledge of this being indispensable for a due appreciation of the generic characters, we have therefore been obliged to seek another type; and we believe that this may be most readily found in *Pentremites Norwoodi*, O. & S., not only from its general acceptance as a typical *Granatocrinus*, but because it was one of the species first referred to this genus by American palæontologists.

The description of *Granatocrinus* given by Meek and Worthen[2] was supplemented by the following remarks:—"The generic formula of this group is exactly the same as that of *Pentremites*, Say, so far as regards the number and arrangement of the pieces forming the body, though the form and proportions of these pieces are so unlike as to give a very different outline and general physiognomy to the entire fossil. They are therefore readily distinguished from Say's genus, as properly restricted, by the irregular oval, elliptical, or subglobose form, concave or less protuberant base, and much narrower and more elongated pseudoambulacral areas, which extend the entire length of the body, so as to give it more the appearance of an Echinoid. They likewise present differences in the arrangement of the ovarian (?) openings of the summit, which are more intimately connected with the interradial pieces, being sometimes excavated one into each lateral margin of these pieces (*G. Sayi*), or in other instances piercing directly through them, so that each pair appears externally as a single opening (*G. melo* and *G. Norwoodi*), though they divide into two distinct canals before passing entirely through the plates. The typical forms of this genus also have the interradial pieces proportionately much larger than in the true *Pentremites*, though this is not a constant character."

On a comparison of the species thus separated from *Pentremites* and united under

[1] A suggestion which we have, to a certain extent, adopted by establishing our genus *Cryptoblastus*.

[2] Report Geol. Survey Illinois, 1866, vol. ii. p. 274.

Granatocrinus, we found that they belonged to two well-defined morphological groups. To the first of these, having for its type *Pentremites Norwoodi*, O. & S., we have elsewhere proposed to restrict the name *Granatocrinus*; while to the other, typified by *Pentremites Sayi*, Shumard, we have applied the name *Schizoblastus.*

The form and general appearance of the calyx presents a remarkable uniformity of type throughout the species which we have retained under the name of *Granatocrinus.* Two broad divisions may be traced—the first after the type of *G. Norwoodi*, the second after that of *G. ellipticus*, G. B. Sby., sp. The form of the body is subglobose in the first division, which includes all the British species except *G. ellipticus* and *G. McCoyi.* These types, which are elongately elliptical (Pl. VIII. figs. 16, 19; Pl. X. fig. 5), form a division by themselves, no other species resembling them in shape. The summit is generally more or less flattened (Pl. II. figs. 32, 33; Pl. IX. figs. 6, 11; Pl. X. fig. 9), or even at times a little depressed (Pl. X. figs. 7, 16). The base is usually small, and flattened or concave. The amount of the concavity varies with the species, the basal plates never being visible in a side view. In *G. Norwoodi* the basal concavity is narrow and deep (Pl. III. fig. 16), in *G. orbicularis* broad and shallow (Pl. IX. fig. 13), the same in *G. ellipticus* (Pl. VIII. fig. 18), rather deeper in *G. Derbiensis* (Pl. IX. figs. 3, 4), and broad and almost flat in *G. campanulatus*, in fact broader in this species than in any other (Pl. VIII. fig. 13).

The relative proportions of the radial and deltoid plates vary considerably: some species have large radials and small deltoids (Pl. II. figs. 32–35; Pl. VII. figs. 5, 6); others small radials and large deltoids (Pl. IX. figs. 1–6). Generic subdivision has before now been attempted, according to the relative sizes of these plates; but, as Messrs. Meek and Worthen have very justly observed, speaking of the deltoids in particular, "There are so many gradations in this character, however, that it does not seem to be possible to make it a means of separating the species into two well-defined sections"[1]. *G. Norwoodi* possesses very large radial plates, extending from the edge of the hollow base almost to the very apex of the calyx, and correspondingly small deltoids (Pl. VII. figs. 10, 12). On the other hand, in the British species, although the radials maintain their general superiority of size in all but one form (Pl. IX. figs. 1–4), the deltoids are longer than in the American type. A gradation, however, is traceable from *G. McCoyi* (Pl. X. fig. 5), in which they are relatively smallest, to *G. orbicularis* (Pl. IX. figs. 11, 12), which possesses the largest deltoid plates, with the exception of *G. Derbiensis* (Pl. IX. figs. 1–4). In the latter species the deltoids attain an inordinately large size, the radial plates being only just sufficiently high to enclose within their sinuses the distal ends of the long ambulacra. In all the species, whether the deltoids are large or small, the spiracles open on the mammillary projections at the apices of these plates; but in *G. campanulatus* they are bounded by nodular elevations of the plates (Pl. IX. fig. 8). Dr. C. A. White has shown that the anal

[1] Report Geol. Survey Illinois, 1866, vol. ii. p. 275.

spiracle in *G. Norwoodi* is bordered on the outer side by a solid projection formed by a part of the deltoid plate [1]. Messrs. Meek and Worthen suggested that the anal plate consisted of three pieces [2], but we have not met with any evidence confirming this view; and we think that the characters of the internal casts to which they refer in support of it are simply due to the presence of the two hydrospire-canals at the sides of the rectum, as shown on Pl. VII. fig. 7.

The ambulacra of *Granatocrinus* are always long, curved, narrow, and reach to the base, the calyx usually resting, when placed in its natural position, on the distal ends of the ambulacra (Pl. II. figs. 32–35; Pl. IX. figs. 1, 2, 11, 12). This appears to be an essential character of the genus, and is one of the points in which it agrees with *Schizoblastus* (Pl. VI. fig. 15; Pl. VIII. fig. 10; Pl. XVI. fig. 13), and also with all the members of Roemer's group Elliptici. The side plates in the ambulacrum of *Granatocrinus*, unlike those of *Pentremites*, do not lie against the sides or edges of the lancet-plate, but actually rest upon it, so as to conceal more or less of its surface (Pl. VIII. figs. 15, 21; Pl. IX. fig. 16; Pl. X. figs. 11, 12). They vary in number according to the species (from twenty to eighty), and are usually transversely elongated. The ambulacra are at times deeply impressed within the prominent edges of the radial sinuses. In *G. Norwoodi*, and in all the British species with one exception, the lancet-plates almost entirely fill up the radial sinuses (Pl. X. figs. 8–12). We have come to the conclusion that in *Granatocrinus*, as restricted by us, there is no under lancet-plate, as there is in *Pentremites* and *Orophocrinus*, and we are glad to find ourselves in accord with Messrs. Wachsmuth and Springer on this point [3]. There is a good deal of variation in the formation of the ambulacral pores. In *G. orbicularis* they are enclosed between the margin of the radial plates, the lower margin of the side plates above, and the upper oblique margin of the outer side plates, and are, roughly speaking, triangular in shape. The result of this is that the pores are excavated wholly in the outer side plates (Pl. IX. fig. 16). In *G. ellipticus* a slightly different arrangement is met with. Here the pores are excavated out of the side plates themselves, the upper edge of the outer side plate being quite straight, and not at all incised (Pl. VIII. fig. 21). In *G. campanulatus* the pores are scarcely excavated in the ambulacral plates at all, but are almost wholly formed in the edges of the radial plates (Pl. VIII. fig. 15). There also appear to be slight modifications in the arrangement of the sockets placed on the side plates. In *G. orbicularis* they terminate narrow grooves which arise from the lower sutures between the side plates and the outer side plates, running almost straight on to the centre of each plate (Pl. IX. fig. 16). In *G. ellipticus*, on the other hand, the grooves communicating with the sockets arise

[1] Boston Journ. Nat. Hist. 1863, vol. vii. no. 4, p. 483.

[2] Report Geol. Survey Illinois, 1873, vol. v. p. 465.

[3] Revision of the Palæocrinoidea, Part II. 1881, t. 19. f. 6.

from the sutures separating the side plates themselves, and must have been in direct communication with the pores (Pl. VIII. fig. 21). In *Granatocrinus* the hydrospires are few in number. *G. Norwoodi* possesses two on each side of an ambulacrum, whilst *G. campanulatus*, *G. orbicularis*, *G. ellipticus*, and *G. Derbiensis* have only one each (Pl. XVII. figs. 3–8). The lancet-plate rests between these two hydrospire-tubes, whose inner walls appear as the hydrospire-plates between it and the sides of the sinus (Pl. X. figs. 12–14). It sometimes helps to support the side plates, as in *G. Norwoodi* (Pl. X. fig. 11; Pl. XI. fig. 14).

Our researches amongst the British species of *Granatocrinus* have not rewarded us by the discovery of any summit-plates closing the central aperture, like those which commonly occur in the American *G. Norwoodi* (Pl. VII. figs. 4, 11, 13). The calyx in this genus is highly ornate. Concentric striæ, often becoming reticulate, or fine granules, arranged in lines, cover the plates (Pl. VI. fig. 21; Pl. VIII. figs. 13, 14, 16, 19; Pl. IX. figs. 1–4, 8–15; Pl. X. figs. 5–10, 16).

Species. The species which we are now able to refer with any certainty to *Granatocrinus*, in its most restricted sense, are the following:—

Pentremites campanulatus, McCoy. Carboniferous Limestone; Derbyshire.
Pentremites Derbiensis, G. B. Sby. Carboniferous Limestone; Derbyshire and Lancashire.
Pentremites elliptica, G. B. Sby. Carboniferous Limestone; Derbyshire, Lancashire, and Yorkshire.
Granatocrinus McCoyi, E. & C. (MS.). Carboniferous Limestone; Lancashire.
Pentremites Norwoodi, O. & S. Upper Burlington Limestone, Subcarboniferous; Iowa, Illinois, Missouri.
Granatocrinus Norwoodi, var. *fimbriatus*, M. & W. var. Upper Burlington Limestone, Subcarboniferous; Iowa.
Pentatrematites orbicularis, G. B. Sby. Carboniferous Limestone; Lancashire.

In addition to the British species here mentioned, two others have been described, viz. *Mitra humerostellata*, Cumberland [1], and *M. Hibernica*, Cumb.[2], which appear to us to fall within the genus *Granatocrinus*. We have, however, quite failed to identify them with any of the later-described species, and they are known to us only through Cumberland's descriptions and figures. Neither are we acquainted with the form for which the Messrs. Austin proposed the MS. name of *Orbitremites globosus* [3].

Of the sixteen species of *Granatocrinus* which have been described in America, *G. Norwoodi* is the only one which we can with any certainty refer to this genus.

[1] Reliquiæ Conservatæ, 1826, p. 35, t. A. figs. 1–3.
[2] *Loc. cit.* p. 34, t. B. figs. 1–4 (bottom group).
[3] Ann. & Mag. Nat. Hist. 1842, vol. x. p. 111.

G. melo is a *Cryptoblastus*; and so also, as we think, are *G. pisum* and *G. projectus*[1]. *G. Sayi* is the type of *Schizoblastus*, to which we also refer *G. melonoides*, and probably *G. lotoblastus*, *G. Missouriensis*, *G. neglectus*, and *G. granulosus*. We believe *G. glaber* to be a *Mesoblastus*, and *G. cornutus* is not improbably an *Heteroblastus*. There remain, then,

Granatocrinus curtus, Shumard. Chester Group; Missouri.
Granatocrinus granulatus, Roemer, sp. St. Louis Group; Kentucky, Alabama, and Tennessee[2].
Granatocrinus Roemeri, Shumard. Chemung Group (*fide* Shumard), but Kinderhook Group (*fide* Miller); Missouri.
Granatocrinus Shumardi, M. & W. Lower Burlington Limestone; Iowa.

G. curtus and *G. Roemeri* were originally described by Shumard under the generic name *Pentremites*[3], and were only subsequently referred to *Granatocrinus*[4]. The structure of the summit is unknown in both types, and we are therefore unable to decide upon their generic position.

The second of the four species mentioned above was described by Roemer[5] from an internal cast under the name of *Pentatrematites granulatus*; but he had seen perfect specimens of it in Troost's collection designated by "dem hier angenommenen Speciesnamen." Shumard and Hambach[6] say, however, that Roemer's species is identical with the *Granatocrinus cidariformis*, Troost, MS., a point about which we can offer no opinion whatever; but in any case we are by no means certain that the former type is congeneric with *Granatocrinus Norwoodi*. Mr. Wachsmuth has sent us a specimen of it which shows the summit; but we cannot make out that it has any spiracles at all (Pl. VI. fig. 22), even the position of the anal opening being very obscure. Under these circumstances we must leave the generic position of this type to be decided by our American colleagues.

Granatocrinus Shumardi is a species which has puzzled us very considerably. There is no trace of spiracles at the central ends of the deltoids in the figure of it which is given by Meek and Worthen[7]; and we are somewhat inclined to think, from the condition of one of Mr. Wachsmuth's specimens, that it may be an elongated

[1] This species may perhaps belong to *Schizoblastus*, but it is described as being closely allied to *Granatocrinus melo*, which is the type of *Cryptoblastus*.

[2] Shumard (Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 375) gives Kaskaskia Limestone as the horizon of this species.

[3] Palæontology in Swallow's 1st and 2nd Ann. Report, Geol. Survey Missouri, 1855, pp. 186, 187.

[4] Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, pp. 375, 376.

[5] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. pp. 363, 364.

[6] Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 375; *ibid.* 1884, vol. iv. no. 3, p. 543.

[7] Report Geol. Survey Illinois, 1868, vol. iii. pl. xviii. f. 6 *b*.

form of *Mesoblastus* comparable to the British *M. elongatus* or *M. Sowerbii* (Pl. VI. fig. 12; Pl. VIII. fig. 1). But in the absence of sufficiently well-preserved material we cannot venture to decide upon the generic position of this rare species.

Distribution. *Granatocrinus*, as now defined, is strictly limited to rocks of Carboniferous age. Five species occur in the Carboniferous Limestone of Yorkshire, Lancashire, and Derbyshire, two of them (*G. Derbiensis* and *G. ellipticus*) being sometimes tolerably abundant.

The only American species definitely known to us (*G. Norwoodi*) is also the type of the genus, and occurs in the Burlington Limestone at the lower part of the Subcarboniferous. If *Pentremites Roemeri* of the Kinderhook Group (Chemung, Shumard) really be a *Granatocrinus*, it is the oldest known species of the genus, which would also extend up into the Chester Group if *Granatocrinus curtus*, Shumard, be rightly so named.

Type. *Pentremites Norwoodi*, Owen and Shumard.

Granatocrinus Norwoodi, *Owen & Shumard*, sp.

(Pl. II. figs. 34–36; Pl. III. fig. 16; Pl. VI. figs. 19, 20: Pl. VII. figs. 1–13; Pl. X. fig. 11; Pl. XI. fig. 14; Pl. XVII. fig. 8.)

Pentremites Norwoodi, O. & S., Journ. Acad. Nat. Sci. Philad. 1850, vol. i. pt. 1, p. 64, t. 7. f. 13, *a–c*.

Pentremites Norwoodi, O. & S., Wisconsin, Iowa, and Minnesota Geol. Report, 1852, p. 591, t. 5 A. f. 13, *a–c*.

Pentremites Norwoodi, White, Boston Journ. Nat. Hist. 1863, vol. vii. no. 4, p. 483.

Elæacrinus Norwoodi, Shumard, Trans. St. Louis Acad. Sci. 1863, vol. ii. no. 1, p. 112.

Granatocrinus Norwoodi, Shumard, *ibid.* 1865, vol. ii. no. 2, p. 375.

Granatocrinus Norwoodi?, Meek & Worthen, Proc. Acad. Nat. Sci. Philad. 1866, p. 258 (*G. fimbriatus*, MS.).

Granatocrinus Norwoodi?, Meek & Worthen, Report Geol. Survey Illinois, 1868, vol. iii. p. 496, t. 18. f. 8 (*G. fimbriatus*, MS.).

Granatocrinus Norwoodi, Meek & Worthen, Proc. Acad. Nat. Sci. Philad. 1869, p. 84.

Granatocrinus Norwoodi, Meek & Worthen, Report Geol. Survey Illinois, 1873, vol. v. p. 465 (note), t. 9. f. 2, *a–e*.

Granatocrinus Norwoodi, Zittel, Handb. Pal. 1879, 1 Bd. 3 Lief. p. 432, f. 305 *b*, p. 435, f. 308 *a* (= *G. fimbriatus*, M. & W.), and 308 *b*.

Granatocrinus Norwoodi, Wachsmuth & Springer, Proc. Acad. Nat. Sci. Philad. 1881, t. 19. f. 6.

Granatocrinus Norwoodi, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 239.

Sp. Char. Calyx globose, or elliptical-globose, sometimes inflated in the lines of the ambulacra; summit more or less concave, base contracted, the calyx resting on the inturned radial lips, which border a deep and funnel-shaped pentagonal cavity; section round or slightly pentagonal, or in one extreme variety decidedly pentagonal;

periphery almost equatorial. Basal plates completely hidden in the columnar cavity, and constituting about two thirds of it, in the form of an inverted deep pentagono-conical cup. Radial plates elongate, extending almost the entire height of the calyx, and slightly turned in below to assist in forming the columnar cavity; limbs ellipsoidal, very long, obliquely truncated above, with the central line of each limb rather concave; interradial sutures deep, sinuses sublinear, narrow, with prominent edges; radial lips prominent, and their apices projecting. Deltoid plates small, thickened, triangular, with broad bases, and almost horizontally placed, often produced upwards into small, tapering tubes. Ambulacra parallel-sided, projecting slightly above the edges of the sinuses; lancet-plate subhexagonal in section, its median groove exposed till near the distal end; side plates very small and numerous[1], lying on the lancet-plate at a high angle. Hydrospires two on each side of an ambulacrum, their sacs large and pyriform; spiracles round, vertically perforating the tube-like projections of the deltoid plates, occasionally double, but the anal spiracle oval, and more nearly on a level with the summit of the calyx, protected on the outer side by a large node or tubercle. Mouth small. Column of round thin joints. Surface of the radial plates bears oblique, rounded, and minutely granular ridges, and intervening impressed lines, directed from the edges of the sinuses laterally towards the interradial sutures, the longer ones converging to the narrow portions of the plates between the radial lips, where they are much crowded together.

Remarks. This is a very remarkable species, and will well repay close and attentive study. The deep columnar cavity is a very striking and characteristic feature. It is deeper in this Blastoid than in any other with which we are acquainted, even *Elœacrinus Verneuili* (Pl. II. fig. 45). A still more noticeable character in many individuals is the extension of all the spiracles, except the anal one, into erect tubular openings, a feature which was first described by Dr. C. A. White[2]. We figure a very beautiful example of these tube-like prolongations (Pl. VII. fig. 5), and are not acquainted with exactly similar structures in any other Blastoid. From an examination of numerous specimens, however, it appears to us that this one must be looked upon as presenting an extreme condition, for in the majority of cases the tubes do not project anything like so far (compare Pl. II. figs. 32–35). The individual figured on Pl. VII. figs. 5, 6, also shows the "solid projection" described by Dr. White as bordering the outer side of the anus. Several of our English species of *Granatocrinus* have nodes or mammillary projections not only over the anal but also over the other four spiracles (Pl. IX. figs. 5, 8, 14, 15). We have not, however, noticed any erect tube-like extensions like those of *G. Norwoodi*. The number of side plates is difficult to estimate; but according to Owen and Shumard there are two hundred plates on each side of an ambulacrum—one hundred side, and one

[1] Owen and Shumard say one hundred.

[2] Boston Journ. Nat. Hist. 1863, vol. vii. no. 4, p. 483.

hundred outer side plates. Dr. C. A. White gives a good description of them, which is well illustrated by our figures (Pl. VII. figs. 10, 12; Pl. X. fig. 11; Pl. XI. fig. 14). The hydrospire-plate, which is well seen in the last two figures, is not so steeply inclined as usual, and so takes more share in supporting the side plates. The pinnules have been described by Meek and Worthen [1] as slender, simple, of uniform size, and each composed of a single row of pieces, thereby not differing essentially from those of *Pentremites*. Through the kindness of Mr. Wachsmuth we are enabled to figure a specimen of *G. Norwoodi*, with the column attached. As already described by Meek and Worthen [2], the joints are round and thin near the calyx, but become thicker and alternately larger and smaller towards the lower part of the stem. Although Mr. Wachsmuth's collection contains several good examples of this species with the summit plates preserved (Pl. VII. figs. 4, 11, 13), yet such cases do not appear to be very common. They enable us to confirm Dr. White's description of the parts in question, but we cannot agree with many of his deductions, as we have explained on pp. 77, 78. The so-called "vault" takes the form of a small dome, and is composed of a limited number of irregular plates of variable size and disposition. The figures given by Meek and Worthen [3] exactly represent the plates as we have seen them; but we have not found the anus ever covered by a single plate, as they represent it [4]. We give a very interesting figure (Pl. VII. fig. 12) of a specimen in Mr. Wachsmuth's collection, in which one of the deltoids is perforated by two spiracles. This appears to lead up to the structure of the spiracles in *Heteroblastus* (Pl. VI. figs. 3, 4), to which we shall refer hereafter.

We have had the advantage of examining a large number of specimens of *G. Norwoodi*, and have succeeded in distinguishing at least six directions in which variation occurs (Pl. II. figs. 32–35):—

1st. In the form of the calyx. Var. A, which we believe to be the species proper, presents a simple globose outline. Var. B is elliptical-globose in outline, being elongated in the direction of the vertical axis, and having a less transverse diameter, in proportion to its height, than Var. A.

2nd. In the breadth of the interradial areas. Var. A has these portions of the calyx almost one third wider than in Var. B, and is therefore usually more pentagonal in outline.

3rd. In the projection of the ambulacra. Extreme forms of the Var. A have a marked inflation in the line of the ambulacra. This is so considerable that were such individuals found alone, without any connecting links with other varieties, they would certainly be described as new species.

4th. In the undue projection of one or sometimes two of the ambulacra only, usually on the anal side, so as to give the calyx a very unsymmetrical appearance.

[1] Proc. Acad. Nat. Sci. Philad. 1866, p. 258. [2] *Ibid.* p. 258.
[3] Report Geol. Survey Illinois, 1873, vol. v. pl. 9. f. 2 *a*. [4] *Ibid.* pl. 9. f. 2 *b*.

These are always extreme forms of Var. A, and indicate a transition towards *Granatocrinus curtus*, Shumard[1].

5th. In the degree and development of the ornament. The granular ridges are much more numerous in some forms of Var. A than they are in others, either of A or of B.

6th. In the development of the short spiracular tubes (compare Pl. II. figs. 32–35; Pl. VII. figs. 3, 5, 6).

All these varietal forms, however, have certain very definite characters in common; *e. g.* the basal concavity, and the more or less tubular spiracles. We do not feel therefore that there is any other course open to us than to retain them all under the name *G. Norwoodi*. It is more than possible that the form Meek and Worthen wished to separate under the name of *G. fimbriatus*[2] is only a well-marked variety of *G. Norwoodi*.

The other American Blastoids which may eventually prove to belong to *Granatocrinus* are distinguishable from *G. Norwoodi* by well-defined characters. The horn-like deltoid plates of *G.* ? *cornutus*, M. and W.[3], are altogether absent in the former type; whilst the outline of the calyx in *G.* ? *curtus*, Shumard[4], at once separates that species, notwithstanding the projecting radii of one variety of *G. Norwoodi*. Again, the larger deltoids, and the ornament, of *G.* ? *granulatus*, Roemer[5], and *G.* ? *Roemeri*, Shumard[6], together with the general outline of the calyx in *G.* ? *Shumardi*, M. & W., distinctly mark them as species which are separate both from one another and from *Granatocrinus Norwoodi*.

Localities and Horizon. Burlington, Iowa; Pleasant Grove, Iowa; near Monmouth, Illinois. [Shumard also gives Hannibal and St. Louis Co., Missouri. Other localities are Clarke Co. and Louisiana, Missouri]: Upper Burlington Limestone, Subcarboniferous.

GRANATOCRINUS ORBICULARIS, *G. B. Sowerby*, sp.

(Pl. IX. figs. 11–16; Pl. XVII. fig. 5.)

Pentatrematites orbicularis, G. B. Sby., Zool. Journ. 1835, vol. v. no. 20, p. 456, t. 33, Supp. f. 5.
Pentremites orbicularis, Phillips, Geol. York. 1836, pt. 2, p. 207, t. 3. f. 9.
Pentatrematites orbicularis, Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 363.
Pentremites orbicularis, Dujardin & Hupé, Hist. Nat. Zooph. Échinod. 1862, p. 95.

[1] Swallow's 1st and 2nd Report, Geol. Survey Missouri, 1855, p. 187, t. B. f. 3, *a*, *b*.
[2] Proc. Acad. Nat. Sci. Philad. 1869, p. 258.
[3] Report Geol. Survey Illinois, 1866, vol. ii. p. 276, t. 20. f. 1.
[4] Swallow's 1st and 2nd Report, Geol. Survey Missouri, 1855, p. 187, t. B. f. 3 *a*.
[5] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 363, t. 6. f. 13.
[6] *Loc. cit.* t. B. f. 2 *a*; Report Geol. Survey Illinois, 1868, vol. iii. p. 498, t. 18. f. 6.

Pentremites orbicularis, Rofe, Geol. Mag. 1865, vol. ii. p. 249.
Granatocrinus orbicularis, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 239.

Sp. Char. Calyx globose; summit converging, concave; base somewhat contracted and faintly concave; section almost round, or very slightly decagonal, sometimes with almost flat sides; periphery nearly equatorial. Basal plates quite concealed; basi-radial sutures confined to the central cavity. Radial plates pentagonal, more than half as long as the calyx, nearly flat-sided, and widening rapidly upwards; bodies remarkably small, concave, and so assisting to form the basal concavity; limbs long and broad, obliquely truncated above; sinuses very narrow, and sublinear, parallel-sided; radio-deltoid sutures forming a wide and open angle. Deltoid plates very large, broadly rhombic, with small depressed and constricted apices, all but the anal one bearing a node or prominence behind the spiracle. Ambulacra very narrow, projecting slightly above the edges of the sinuses; median grooves of the lancet-plates exposed between half and two thirds the length of the ambulacra; side plates very numerous, comma-shaped; outer side plates curved, and excavated for the pores, which are more or less triangular. One hydrospire-tube on each side of an ambulacrum; their sacs almost circular in section. Spiracles small, triangular-pyriform, opening inwards and obliquely upwards; anal spiracle much larger than the others. Ornament of very minute granules arranged in lines parallel to the margins of the plates, with a stronger series bordering the edges of the sinuses.

Remarks. G. orbicularis appears to be a tolerably abundant species in certain localities, and may be readily recognized by its orbicular or globose outline and large deltoid plates. It may be distinguished from *G. Derbiensis* by the position of the radio-deltoid sutures, which in *G. orbicularis* are above the equator (Pl. IX. figs. 11, 12), whilst in the latter species they are near the base (figs. 1–4, 6). Except as regards these sutures, the resemblance between these two species is a close one. In *G. campanulatus* the base is broad and flat (Pl. VIII. fig. 13), and although the radio-deltoid sutures occupy nearly the same position the angle which they form is a very different one (fig. 14), and the height of the calyx, as compared with its breadth, bears no relation to the same measurements in *G. orbicularis.*

The ambulacral pores of the latter type are enclosed between the margins of the radials, the lower margins of the side plates above, and the upper oblique margins of the outer side plates below, and are, roughly speaking, triangular in shape (Pl. IX. fig. 16).

We have had the advantage of studying the specimen which was figured both by Mr. G. B. Sowerby and by Prof. John Phillips. There is a considerable variation both in the general shape of the calyx (Pl. IX. figs. 11, 12), and in the capacity of the peristome (figs. 14, 15).

Localities and Horizon. Bolland District, Lancashire; Clitheroe, Lancashire (Presented by the late J. Rofe, Esq., F.G.S.): Carboniferous Limestone.

GRANATOCRINUS DERBIENSIS, *G. B. Sowerby*, sp.

(Pl. VI. fig. 23; Pl. IX. figs. 1–7; Pl. XI. figs. 11–13; Pl. XVII. fig. 4.)

Pentremites Derbiensis, G. B. Sby., Zool. Journ. 1825, vol. ii. no. 7, p. 317, t. 11. f. 3 (4 figs.).
Pentremites Derbiensis, Phillips, Geol. York. 1836, pt. 2, p. 207, t. 3. f. 10.
Orbitremites Derbiensis, T. & T. Austin, Ann. & Mag. Nat. Hist. 1842, vol. x. p. 111.
Pentremites Derbiensis, McCoy, Synop. Carb. Lime. Foss. Ireland, 1844, p. 174.
Pentremites Derbiensis, McCoy, Brit. Pal. Foss. 1851, fasc. 1, p. 124.
Pentatrematites Derbiensis, Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 364.
Pentremites Derbiensis, Dujardin & Hupé, Hist. Nat. Zooph. Échinod. 1862, p. 95.
Granatocrinus Derbiensis, E. &. C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 239.

Sp. Char. Calyx subglobose, at times approaching spheroidal; summit flattened; base small, concave, and very much contracted; section roundly pentagonal, with the sides at times a little flattened; periphery either at or a little above the equator. Basal plates small and confined within the basal cavity. Radial plates small, short, wholly visible in an inferior view, pentagonal, expanding rapidly upwards, lateral margins widely divergent; limbs short, more or less horizontally truncated above; sinuses very long and narrow, sometimes almost reaching the basal concavity; lips very pronounced and projecting; radio-deltoid sutures variable in position, but always near the base, forming a very wide obtuse angle, and in some cases almost flat, or horizontal; the union of the basal and radial plates forms a short and wide cup, less than one third the entire height of the calyx. Deltoid plates very large, forming quite two thirds of the entire body, broadly triangular, attenuating slowly upwards, and much curved, with their upper ends almost horizontal, and the apices constricted, the four anterior ones each bearing a node behind the spiracle. Ambulacra very narrow, hardly projecting above the general surface of the calyx, and approaching one another somewhat closely at the dorsal pole; lancet-plate entirely, or almost entirely, covered by the side plates; ambulacral groove very fine; side plates small, oblong, very numerous, probably about sixty. One hydrospire on each side of an ambulacrum; tubes large and wide; sacs pyriform. Spiracles oval or slightly pyriform, opening inwards and upwards, the anal spiracle larger and more triangular. Mouth small. Column round; joints long, and cylindrical. Surface of the radial and deltoid plates coarsely granular.

Remarks. Granatocrinus Derbiensis is noticeable as being the only British species in which the whole of the radial plates are visible in a basal view (Pl. IX. figs. 3, 4). The deltoid plates are likewise larger in *G. Derbiensis* than in any of the others, and in some instances the radio-deltoid sutures are almost horizontal (Pl. IX. fig. 6). As regards the length of the ambulacra, and their proximity to the basal concavity, *G. Derbiensis* is intermediate between *G. orbicularis* (Pl. IX. fig. 13) or *G. ellipticus* (Pl. VIII. fig. 18) and *G. campanulatus* (Pl. VIII. fig. 13). They are not quite so

long as in the two first-named species, but longer than in the latter type (Pl. IX. figs. 3, 4). The base of the calyx is much more contracted in some individuals than in others, as may be seen from these two figures, and in those with the narrowest or most contracted bases the columnar cavity is deepest. The granular ornament is occasionally arranged near the radio-deltoid sutures in lines parallel to the latter, and is more strongly marked than on other portions of the calyx.

This species appears to vary to a slight extent in the outline of the calyx, owing to differences in the degree of prominence of the ambulacra (Pl. IX. figs. 1, 2, 6).

Localities and Horizon. Grassington, Derbyshire; Whitewell, in Bolland, Lancashire; Clitheroe, Lancashire (Presented by the late J. Rofe, Esq., F.G.S.): Carboniferous Limestone. [Prof. McCoy recorded this as an Irish species, but without locality.]

GRANATOCRINUS CAMPANULATUS, *McCoy*, sp.

(Pl. VIII. figs. 12–15; Pl. IX. figs. 8–10; Pl. X. figs. 9, 10; Pl. XVII. fig. 3.)

Pentremites campanulatus, McCoy, Ann. & Mag. Nat. Hist. 1849, vol. iii. p. 249.
Pentremites campanulatus, McCoy, Brit. Pal. Foss. 1851, fasc. 1, p. 123, t. 3 D. f. 9.
Pentatrematites campanulatus, Roemer, Archiv f. Naturgesch. 1851, vol. xvii. Bd. i. p. 361, t. 8. f. 4.
Pentremites campanulatus, Dujardin & Hupé, Hist. Nat. Zooph. Échinod. 1862, p. 94.
Granatocrinus campanulatus, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 239.
Granatocrinus pisiformis, E. & C. (MS.), *ibid.* p. 239.

Sp. Char. Calyx small, depressed globose, or broadly bell-shaped; summit gently rounded; base broad, truncate, and flattened, almost as wide as the calyx, with a very shallow central concavity; section above the radio-deltoid sutures slightly pentagonal, but rounded, or even a little decagonal below; periphery equatorial, or slightly nearer the base than the summit. Basal plates small, limited to the shallow central cavity. Radial plates broadly pentagonal, a little more than half the length of the calyx; limbs almost flat, with parallel margins, and their upper ends obliquely truncate; lips moderately prominent; sinuses very long, narrow, and parallel-sided; interradial sutures not in concavities. Deltoid plates large, unequally rhombic, somewhat concave in the middle line, and constricted at their apices, all five often bearing large prominent nodes. Ambulacra projecting slightly above the edges of the sinuses; side plates from fifteen to thirty; lancet-plate not entirely concealed by the side plates; ambulacral groove wide and open; pores almost wholly excavated in the edges of the radial sinuses. Spiracles triangular-pyriform, opening horizontally, with thickened edges, and protected on the outer side by the large deltoid nodes. Column circular. Ornament of rather coarsely tuberculated lines parallel to the margins of the plates.

Remarks. Granatocrinus campanulatus appears to be distinguished by its bell-like

form, flat base, nearly median radio-deltoid sutures, and the large nodes on the deltoid plates which protect all the spiracles including the large anal one (Pl. IX. fig. 8).

Prof. McCoy has very justly observed, "If we suppose the lower third abruptly cut off a *P. ellipticus*" [= *Granatocrinus ellipticus*, G. B. Sby. sp.], "we should have a good idea of this little species." The broad flat base of *G. campanulatus* is unknown in any other British species of *Granatocrinus*, the one which comes nearest being the little *G. McCoyi*, nobis (Pl. X. fig. 16). The position of the radio-deltoid suture varies slightly, being highest in the smaller individuals of the typical form (Pl. VIII. fig. 14; Pl. IX. fig. 10), and generally at about the same level as in *G. ellipticus* (Pl. VIII. figs. 16, 19; Pl. X. fig. 16). The spiracles are relatively larger in *G. campanulatus* (Pl. VIII. fig. 12; Pl. IX. fig. 8; Pl. X. fig. 10) than in this last species or in *G. orbicularis* (Pl. VIII. fig. 17; Pl. IX. figs. 14, 15), and are more like those of *G. Derbiensis* (Pl. IX. fig. 5), the opening being bordered by a distinct rim; but the present form differs from all these three species, and also from *G. McCoyi* (Pl. X. fig. 8), in having a node at the distal edge of the anal spiracle (Pl. IX. fig. 8).

The lancet-plate of *G. campanulatus* is relatively very wide, and the hydrospire-plate is scarcely visible (Pl. VIII. fig. 15); while the pores are in closer relation with the edges of the sinuses than in other species of the genus, the side plates taking but little share in their formation.

The shape of the calyx presents the usual amount of variation, an extremely flattened form being shown on Pl. X. fig. 9. The small individual which is figured on Pl. IX. figs. 8, 9, was formerly regarded by us as a distinct species, which we proposed to call *G. pisiformis* [1]; but we have since been led to think that it is only a young form with a more strongly granular calyx and larger nodes on the deltoids than occur in mature individuals.

We are indebted to Prof. T. McKenny Hughes for the loan of McCoy's original types of this species from the Woodwardian Museum, Cambridge.

Localities and Horizon. Bolland District, Lancashire; Clitheroe, Lancashire (Presented by the late J. Rofe, Esq., F.G.S.): Carboniferous Limestone.

Granatocrinus McCoyi, sp. nov.

(Pl. X. figs. 5–8.)

Granatocrinus McCoyi, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 239.

Sp. Char. Calyx small, slender, straight-sided, elongately nut-shaped; summit small, subtruncate; base relatively broad, truncated, flat, with a very small and shallow central concavity; section pentagonal; periphery nearly equatorial. Basal plates very minute, and confined to the shallow central depression. Radial plates about half as long as the calyx, or perhaps rather more so; bodies small; limbs

[1] Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 239.

slightly arched, obliquely truncated above; sinuses relatively broad, tapering gradually; lips prominent, but hardly extending as low as the truncate base; interradial sutures on the flat sides, not in concavities. Deltoid plates elongately and irregularly rhombic, slightly concave in the middle line, sometimes with an ill-defined longitudinal ridge in the concavity. Ambulacra subpetaloid, projecting a little above the sides of the sinuses; lancet-plates exposed for a portion of their length; side plates fifteen to twenty. Hydrospires unknown. Spiracles oval-triangular, opening more or less horizontally, the four smaller ones traversed by incomplete, but well-marked septa. Mouth small. Ornament consists of rather strong granules arranged in lines parallel to the margins of the plates.

Remarks. This little species is intermediate in its characters between *G. ellipticus* and *G. campanulatus.* It possesses the elongated calyx of the former (Pl. VIII. figs. 16, 19), and the truncated and flattened base of the latter type (Pl. VIII. fig. 13). The prominence of the constricted apices of the deltoids gives to *G. McCoyi* a rather marked appearance, and they specially assist in giving a truncated look to the summit (Pl. X. fig. 8). The spiracles would, at first sight, appear to be constructed as in the type for which we have proposed the name of *Mesoblastus*, and the strong septa visible in them would favour this idea. But they are true perforations of the deltoids, and are formed without any assistance from the side plates.

It affords us much pleasure to name this species in honour of Prof. F. McCoy, as one of the pioneers of British Palæontology.

Locality and Horizon. Clitheroe, Lancashire (Presented by the late J. Rofe, Esq., F.G.S.): Carboniferous Limestone.

Granatocrinus ellipticus, *G. B. Sowerby*, sp.

(Pl. VI. fig. 21; Pl. VIII. figs. 16–20; Pl. X. figs. 12–16; Pl. XVII. figs. 6, 7.)

Pentremites elliptica, G. B. Sby., Zool. Journ. 1826, vol. ii. no. 7, p. 317, t. 11. f. 4 (4 figs.).
Pentremites ellipticus, Phillips, Geol. York. pt. 2, 1826, p. 207, t. 3. f. 6–8.
Pentremites ellipticus, McCoy, Synop. Carb. Lime. Foss. Ireland, 1844, p. 174.
Pentatrematites ellipticus, Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 360.
Pentremites ellipticus, McCoy, Brit. Pal. Foss. 1851, fasc. 1, p. 124.
Pentremites ellipticus, Dujardin & Hupé, Hist. Nat. Zooph. Échinod. 1862, p. 93.
Pentremites ellipticus, Rofe, Geol. Mag. 1865, vol. ii. t. 6. f. 7.
Granatocrinus ellipticus, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 239.

Sp. Char. Calyx elliptical, acorn-shaped, or elliptical subglobose; summit rounded and contracted; base narrow and concave, with a wide, shallow, central depression; section faintly pentagonal or almost round, with the sides flat, periphery nearly equatorial. Basal plates small, outwardly concave, and confined to the central depression. Radial plates large, broadly pentagonal, very narrow below, expanding upwards, and extending over more than half the height of the calyx; bodies very

small, concave, with a central depression; limbs broad, obliquely truncated above; sinuses very long, almost reaching to the basi-radial sutures; sides parallel, and with sharp edges; lips acute; radio-deltoid sutures either equatorial or slightly nearer the summit, broadly V-shaped, and each half either straight or gracefully curved upwards. Deltoid plates elongately and unequally rhombic, acutely pointed and constricted at their inner ends, sometimes with a faint and granular median ridge; their apices acutely pointed, constricted, and thickened so as to form nodes. Ambulacra narrow, not projecting above the edges of the sinuses; lancet-plate exposed in the median line almost throughout its entire length; side plates forty-five and probably more, their inner ends projecting above the edges of the food-groove; pores very numerous, excavated out of the side plates. One hydrospire-tube on each side of an ambulacrum; its sac large and round, or oval in section. Spiracles perforating the enlarged apices of the deltoids, and opening obliquely inwards and upwards. Ornament on the radials and deltoids consists of a fine granulation arranged in lines parallel to the margins of the plates.

Remarks. This is certainly the most abundant of all the British Blastoids, *G. Derbiensis* being the only one which approaches it in this respect. The Rofe collection contains several fragments of Carboniferous Limestone from Lancashire which are full of broken calyces of this species, many of which are of the utmost value from the way in which they illustrate certain points of structure (Pl. VIII. fig. 20; Pl. X. figs. 12–15); but we have been quite unable to obtain any information as to the particular horizon or locality at which they were found.

G. ellipticus is readily distinguished from *G. Derbiensis* by the smaller size of its deltoid plates, but it resembles that species (Pl. IX. figs. 3, 4), and also *G. orbicularis* (Pl. IX. fig. 13), in the approximation of the ambulacra to the basiradial sutures, though it is closer in this species than in any other. Furthermore the concave and narrow base is altogether different from the broad flat base of *G. campanulatus* and of *G. McCoyi* (Pl. VIII. fig. 13; Pl. X. fig. 6). The nearest ally of *G. ellipticus*, in the characters of the summit as well as in those of the base, is unquestionably *G. orbicularis* (Pl. VIII. figs. 17, 18; Pl. IX. figs. 13–15). But it is readily distinguished by its more globular calyx and larger size, and also by the different characters of its ambulacra. The proximal edges of its outer side plates are cut away to form the hydrospire-pores (Pl. IX. fig. 16), the distal edges of the side plates being quite straight while the grooves which end in the sockets that they bear start from the distal edges of the outer side plates. On the other hand, in *G. ellipticus* the pores are excavated out of the side plates themselves (Pl. VIII. fig. 21), the upper edges of the outer side plates being quite straight, and not at all emarginate. The grooves communicating with the sockets on the side plates arise from the sutures separating the side plates themselves, and must have been in direct communication with the pores. The granular ornament of the calyx in well-preserved specimens is very coarse

(Pl. VI. fig. 21), more so than in any other species of the genus, except perhaps *G.? granulatus*, Roemer[1] (Pl. VI. fig. 22); but it is rarely preserved at all well.

We are acquainted with two well-marked varieties of *G. ellipticus*, both of which were originally illustrated by Mr. G. B. Sowerby, though only one was figured by Prof. Phillips. In one of these (Pl. VIII. fig. 16) the radio-deltoid sutures are straight and direct, forming a large open V[2]. In the second variety, however, these sutures are gracefully curved upwards (Pl. VIII. fig. 19) so as to form a V resembling a "broad arrow"[3]. In the variety with the straight sutures there is a corresponding increase in the width of the upper portion of the calyx, the summit being by no means so contracted as in the other form. A small and more coarsely granular example of this type is shown on Pl. X. fig. 16.

Many of the fragmentary and more or less weathered specimens of *G. ellipticus* in the Rofe collection have been of the greatest importance to us in elucidating obscure points of structure (Pl. VIII. fig. 20; Pl. X. figs. 12–15). These have been already explained on pp. 48–50, 92, &c.

Localities and Horizon. Bolland District, Lancashire; Clitheroe, Lancashire (Presented by the late J. Rofe, Esq., F.G.S.); Preston, Lancashire: Carboniferous Limestone. [Prof. McCoy quotes this form as an Irish species, but does not record the locality.]

Genus HETEROBLASTUS[4], gen. nov.

Gen. Char. Calyx generally resembling that of *Granatocrinus* in the form and proportion of its component parts. The proximal ends of the deltoids are produced upwards as short stout processes, with their bases notched by the spiracles which lead into canals lodged in grooves on the inner faces of the deltoids. Radial sinuses wide, their edges sloping gently downwards to the slightly petaloid ambulacra.

Remarks. We have established this genus for the reception of a single species of very remarkable character, which differs in the structure of its spiracles from any of the preceding genera.

The material at our disposal is not very well preserved; but it is sufficient to show the relations of the deltoid plates and spiracles. The proximal ends of the deltoids are produced upwards into short and blunt spine-like processes, some of which occasionally seem to be in two parts (Pl. VI. fig. 3), though we do not think that this is really the case. A minute lateral opening is visible at the base of each process, between it and the ambulacrum; and an internal view of an isolated deltoid plate (Pl. VI. fig. 4) shows that these openings lead into gutter-like channels, excavated in the substance of the plate for the reception of the proximal ends of the two hydrospire-canals. In the posterior interradius, however, there seems to be a single

[1] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 363, t. iii. f. 13.

[2] Sowerby's two upper figs. *loc. cit.*, and Phillips's middle fig. *loc. cit.*

[3] Sowerby's middle fig. *loc. cit.*

[4] *ἕτερος*, unusual.

anal spiracle (Pl. VI. fig. 5), though we should not like to speak positively upon this point.

The spiracles of *Heteroblastus* are thus in pairs like those of *Schizoblastus.* But instead of leading downwards into the radial sinus beneath the ambulacra, as in most Blastoids, the hydrospire-canals of each interradius first approach one another in grooves on the inner faces of the deltoids (Pl. VI. fig. 4); and it is in consequence of their relation to these plates that we have associated the genus with *Granatocrinus.* Its ambulacra are rather more petaloid than in that type, and in our British species they are depressed some little way below the edges of the wide radial sinuses which slope down to meet them (Pl. VI. figs. 1, 2). So far as we can make out, all these characters are repeated in a Blastoid from the St. Louis Limestone of Illinois, which was described by Meek and Worthen[1] in 1861 as *Pentremites cornutus*, and was afterwards referred to *Granatocrinus*[2]. We quote their description—"Radial pieces . . . . very thick and rising into prominent carinæ on each side of the pseudo-ambulacral fields. Interradial pieces of moderate size, and each projecting out in the form of a very prominent, compressed horn-like process. Pseudo-ambulacral areas very narrow or lance-linear, and deeply implanted between the very prominent carinated forks of the radial plates." The summit of this species is unknown, but the side view of it, which is given by Meek and Worthen, is remarkably like our *Heteroblastus Cumberlandi* (Pl. VI. fig. 1), especially in the appearance of the ambulacra and of the radial sinuses. It has smaller deltoids, however, these being confined to the large processes round the peristome, instead of forming the greater portion of the calyx as in our species.

We are indebted for the material on which we have established *Heteroblastus* to our friend Mr. James Bennie, of the Geological Survey of Scotland, who discovered the specimens in 1884, and has thereby added a new genus to the British Blastoid fauna.

Distribution. The genus is limited in England to the Yoredale shales of Northumberland, but there seems to be a second species in the Subcarboniferous system of America.

Species. We place the two following forms under this genus:—

Heteroblastus Cumberlandi, sp. nov. Yoredale Shales, Carboniferous Limestone: Northumberland.

?*Pentremites cornutus*, M. & W. St. Louis Limestone, Subcarboniferous: Illinois.

Type. Heteroblastus Cumberlandi, sp. nov.

[1] Proc. Acad. Nat. Sci. Philad. 1861, p. 141.

[2] Report Geol. Survey Illinois, 1866, vol. iii. p. 276, pl. 20. fig. 1.

HETEROBLASTUS CUMBERLANDI, sp. nov.

(Pl. VI. figs. 1–6.)

Sp. Char. Calyx small, olive-shaped, contracted at both poles; summit small, concave, surrounded by small, projecting, interradial processes; base small, contracted, and concave centrally; section decagonal; periphery almost equatorial. Basal plates very small. Radial plates short, forming about one third the length of the calyx, their lateral margins widely divergent; bodies very small; limbs with steep sides, obliquely truncated above; lips small, but prominent, and projecting below the concave base; interradial sutures in slight concavities. Deltoid plates long, lanceolate, nearly two thirds the length of the calyx, and concave in the middle line, produced above the summit into short, sharp, erect processes; radio-deltoid sutures strongly marked; radio-deltoid sinuses long, tapering at both ends, the deltoid edges thickened and granulated, the radial edges sharp and plain. Ambulacra subpetaloid below the edges of the sinuses; lancet-plates apparently exposed in the median line for almost the whole length of the ambulacra; side plates small, from twenty-five to thirty; pores piercing the radial and deltoid plates. Hydrospires unknown. Spiracles beneath the projecting apices of the deltoids. Mouth unknown. Column round, composed of slender dice-box-shaped joints. The ornament of the radial plates consists of strong granular lines parallel to the edges; surface of the deltoids granulo-vermiculate, but with several (usually three) coarse ridges parallel with the radio-deltoid sutures; deltoid margins of the sinuses with coarse granules.

Remarks. This exceedingly interesting little Blastoid may be distinguished by its olive-like form, the erect spine-like prolongations of the deltoids, and its small radial plates. In the position of the radio-deltoid sutures it resembles two other British Blastoids, *Granatocrinus Derbiensis* (Pl. IX. figs. 1, 2) and *Schizoblastus Rofei* (Pl. VIII. fig. 10).

We have great pleasure in dedicating this species to the late George Cumberland of Bristol, who was the earliest writer on British Blastoids.

Locality and Horizon. Gunnerton Burn, near Hexham, Northumberland: Yoredale Shales, Carboniferous Limestone. (Presented by Dr. P. H. Carpenter, F.R.S.)

Family *CODASTERIDÆ, E. & C.*, 1886.

Definition. Base usually well developed and sometimes very long. Some or all of the hydrospire-slits pierce the calyx-plates on the sides of the radial sinus, restricted portions of which may remain open as the spiracles.

Remarks. The four genera which we include in this family present a great diversity of external form, though they have certain very definite morphological characters in common. *Cryptoschisma Schulzi*, *Phænoschisma Verneuili*, *Codaster trilobatus*, and

Orophocrinus verus are totally unlike one another in general appearance (Pl. V. fig. 26; Pl. XI. fig. 5; Pl. XIII. fig. 3; Pl. XV. fig. 1); but they all agree in having a tolerably high basal cup, and also in the general characters of the hydrospires. The slits are excavated either wholly or partially in the substance of the calyx-plates, and are not simply the upper openings of lamellar tubes, which are more or less independent of these plates as in other Blastoids (Pl. V. fig. 5; Pl. X. figs. 12–14; Pl. XVI. fig. 20). In *Codaster* and *Phænoschisma* some or all of the slits are permanently open at the sides of the ambulacra (Pl. XI. figs. 1–6; Pl. XII. figs. 1–6; Pl. XIII. figs. 1, 4, 6, 8; Pl. XIV. figs. 1–12). But in *Cryptoschisma* (Pl. V. figs. 23, 24) the ambulacra are so wide that they entirely conceal the hydrospire-slits, a condition which is almost reached in *Phænoschisma caryophyllatum* (Pl. XIV. fig. 3). The slits are partly visible in some species of *Orophocrinus* (Pl. XIV. figs. 15, 18), but in the more typical species they are rather more closely approximated and grouped together near the bottom of the radial sinus, where they are overlapped by the linear ambulacra and so concealed from view (Pl. XV. figs. 4, 10; Pl. XVII. figs. 12–14). In this genus, too, the deltoids appear on the exterior of the calyx above the radial limbs (Pl. XIV. figs. 14–18; Pl. XV. figs. 1, 6), which is not the case in either *Codaster*, *Phænoschisma*, or *Cryptoschisma*. These facts enable us to divide the Codasteridæ into two subfamilies Phænoschismidæ and Cryptoschismidæ, the first of which is very well defined, but the second less so.

Both are represented in the Lower Devonian of Spain; while the former occurs in America as well, each genus passing up into the Carboniferous Limestone on both sides of the Atlantic. Of the Cryptoschismidæ, however, one genus is limited to the Spanish Devonian, and the other to the Carboniferous of Britain, Belgium, and America.

(i.) Subfamily PHÆNOSCHISMIDÆ, *E. & C.*, 1886.

Definition. Eight or ten groups of hydrospire-slits, which are partially or entirely visible. Deltoids limited to the summit, not appearing externally.

Remarks. The characters of this subfamily are so well shown in our figures on Pls. XI.–XIV. that we need say but little about it. Apart from the direct communication of the hydrospires with the exterior, it is chiefly distinguished by the position of the radio-deltoid suture, which starts from the distal end of the oral crest and cuts the hydrospire-slits more or less directly at right angles (Pl. XI. figs. 3, 5, 6; Pl. XIII. figs. 1, 4, 8). *Phænoschisma*, like most other regular Blastoids, has hydrospires in the anal interradius; but these are absent in *Codaster* (Pl. XII. figs. 1, 4, 8; Pl. XIII. figs. 1, 4, 7), which is thus as sharply defined a genus as *Elæacrinus* is. Its relations to *Phænoschisma* are shown in the following table:—

Hydrospire-slits entirely visible, but none in the anal interradius.	*Codaster*, McCoy.
Hydrospire-slits partially concealed by the ambulacra, and present in the anal interradius.	*Phænoschisma*, E. & C.

Genus CODASTER[1], *McCoy*, 1849.

? "*New Genus*," Phillips, Ill. Geol. York. pt. 2, 1836, p. 208.
Codaster, McCoy, Ann. & Mag. Nat. Hist. 1849, vol. iii. p. 250.
Codonaster, Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 381.
Codaster et *Codonaster*, McCoy, Brit. Pal. Foss. 1851, fasc. i. p. 122, t. 3 D (expl. of).
Codonaster, Roemer, in Bronn's Lethæa Geogn., Dritte Auflage, 1852, Theil ii. p. 258.
Codonaster, Pictet, Traité de Pal. sec. édit. 1857, tom. iv. p. 295.
Codonaster, Bronn, Klassen und Ordn. Thier-Reichs, 1860, Bd. ii. p. 189.
Codonaster, Dujardin & Hupé, Hist. Nat. Zooph. Échinod. 1862, p. 101.
Codonaster, Rofe, Geol. Mag. 1865, vol. ii. p. 250.
Codaster, Billings[2], American Journ. Sci. 1869, vol. xlviii. p. 78, 1870; *ibid.* vol. xlix. p. 54.
Codonaster, Zittel, Handb. Pal. 1879, 1 Bd. 3 Lief. p. 424.
Codaster, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 230.
Heteroschisma, Wachsmuth, Report Geol. Survey Illinois, 1883, vol. vii. p. 352.
Heteroschisma, Wachsmuth, Proc. Davenport Acad. Nat. Sci. 1885, vol. iv. p. 82.

Gen. Char. Calyx inverted conical or pyramidal, sometimes ovoid; base obtusely trilobate, or tapering to a more or less acute point; summit usually broad, sometimes abruptly truncated and flattened, or gently convex, and presenting a stellate appearance, which is due to the alternation of the radiating oral ridges with the ambulacra; section, as a rule, distinctly pentagonal; periphery variable in position, but always nearer to the summit end of the calyx. Basal plates forming a conical or triangular cup, usually deep. Radial plates large, the proximal ends always more or less bent inwards horizontally to assist in forming the summit, and never deeply excavated by the sinuses. Deltoid plates wholly confined to the summit, four of them irregularly triangular, and bearing prominent, convex, lanceolate oval ridges; the fifth or anal deltoid more triangular than the others, devoid of a ridge and pierced by the anus. Ambulacra petaloid, or narrow and linear; lancet-plates, as a rule, deeply excavated for the side plates. Spiracles absent. Hydrospires pendent, in eight groups, suspended vertically within the calyx, two in each of the four regular interradii, but wanting in the azygos one. The tubes open externally by a variable number of

[1] There is no doubt that *Codonaster* is etymologically more correct than *Codaster*, as pointed out by Roemer. As in the cases of *Pentremites* and *Troostocrinus*, however, we use *Codaster* on the principle of *plurimorum auctorum*.

[2] For the same paper, see also Canadian Nat. and Geol. 1869, vol. iv. pp. 287 and 429; Ann. & Mag. Nat. Hist. 1870, vol. v. pp. 261 and 412.

elongated slits, which are separated by intervening ridges, and are excavated partly in the truncated upper surfaces of the radials and partly in the deltoids. They are subparallel to the ambulacra, the overlapping side plates of which may partially conceal one or more of them. Mouth small. Anus large, ovate or rhombic. Column small, composed of round or obscurely pentagonal joints. Ornament consisting of fine lines arranged parallel to the margins of the plates.

History. The genus *Codaster* was proposed by Prof. F. McCoy in 1849, and two species were described by him from the Carboniferous Limestone of the North of England. In 1851 Prof. F. Roemer altered the spelling of the name from *Codaster* to *Codonaster*, in order to make it etymologically correct, and his emendation was adopted by Prof. McCoy in the explanation of one of the plates of the 'British Palæozoic Fossils'[1]. The name has been similarly spelt by Pictet, Bronn, Dujardin and Hupé, and by other European palæontologists, though we prefer to retain the original spelling, as has been invariably done in America. The first species of *Codaster* described in the lattter country was the *C. alternatus* of Mr. S. S. Lyon[2], from the Devonian rocks of Kentucky, and three years afterwards (in 1858), Dr. B. F. Shumard[3] added two others, *C. pyramidatus* and *C. Americanus* from similar horizons in Kentucky and Ohio. In 1861, a fourth American species was described by Prof. James Hall[4] from the Burlington Limestone, under the name of *C. Whitei*. It is an ovoid form with narrow ambulacra. Hall says the interradii "appear to be composed of separate linear plates, like the pectinated rhombs of Cystideans; and in one place, where broken through, they are seen to be disconnected almost to the inner faces of the substance, giving the appearance of numerous thin parallel laminæ." McCoy had already given a description of this structure in his generic diagnosis, which Hall seems to have altogether ignored, and McCoy had further noted its absence in the azygos interradius, a point to which Hall makes no reference. We are therefore unable to determine from his description whether *Codaster Whitei* is properly so named, or should be referred to *Phænoschisma*. Hall's description of the hydrospires was, however, an improvement on McCoy's, and foreshadowed the important discoveries made by the late Mr. John Rofe, published in 1865. He found, by means of thin sections prepared for the microscope, that the ridges on the striated interradial areas "are the tops of a series of folds of a thin test or membrane; the alternate folds being so united at the ends, as to form a series of long, but very narrow sacs." For these organs Rofe suggested a probable respiratory character[5]. In 1869 his views were adopted by the late Mr. Billings, who termed these tubular organs

[1] *Op. cit.* Plate 3 D.

[2] D. D. Owen's 3rd Report Geol. Survey Kentucky, 1857, p. 493.

[3] Trans. St. Louis Acad. Sci. 1858, vol. i. pt. 2, p. 239.

[4] Boston Journ. Nat. Hist. vol. viii. p. 327.

[5] Geol. Mag. 1865, vol. ii. p. 251.

"hydrospires," and further showed that the ambulacra of *Codaster* were devoid of pores, the so-called pores being really sockets which received the bases of the ambulacral appendages [1]. McCoy noticed in 1849 that the anal interradius lacks the "sulcation" which appears over the rest of the summit; and further researches by Billings in 1870 showed the full complement of hydrospires to be incomplete by two groups, those of the anal interradius, which is occupied solely by the large vent; while the external openings of the hydrospires are independent, and not united to a common hydrospire-tube, as in other genera of the Blastoidea [2].

Remarks. The definition of the genus given by Prof. McCoy may be taken, on the whole, as accurately describing its characters. The radial plates (McCoy's supra-basals), however, not only "reach to the truncated summit," but they are more or less inturned at the edge of the latter towards the apex, so as to form limbs in the usual way, and enclose narrow radial sinuses. But the summit of *Codaster* does not present the complexity of structure ascribed to it by Prof. McCoy and other writers. Deltoids are present, appearing as diamond-shaped plates on the truncated summits of well-preserved specimens (Pl. XIII. figs. 1, 4, 8). Four of these bear along their median line the "thick rapidly tapering ridges" of McCoy, or, as we term them, oral ridges, which are in no way an abnormal structure, but only represent the crests of the deltoids of other genera.

These deltoid plates were first discovered by Roemer [3], who detected the radio-deltoid sutures which start from the ends of the oral ridges, and run transversely across the hydrospire-slits till they disappear under the ambulacra (Pl. XII. figs. 1, 4, 6; Pl. XIII. figs. 1, 4, 8). Neither Lyon, Shumard, Hall, nor any American palæontologist has ever noticed them, however, when describing new species of *Codaster*; though, as far as our experience goes, there are few individuals which do not show one or more of the sutures, and the presence of deltoids is at once revealed when the summit is ground away a little (Pl. XII. fig. 8).

We have been quite unable to detect the supplementary basal plates described by Mr. S. S. Lyon in any species examined by us [4]; and we need hardly say that we cannot accept his statements as to the "pieces" of the summit which lie between the hydrospire-slits being "evidently capable of" compression or depression.

After a careful examination of Rofe's material, we are glad to be able to add our testimony to the accuracy of his description of the hydrospire-apparatus in *Codaster*. As previously stated, there are only eight groups of slits (Pl. XII. figs. 1, 4; Pl. XIII. figs. 1, 4) instead of ten as in the closely allied *Phænoschisma* (Pl. XIV. figs. 5, 11)

[1] American Journ. Sci. 1869, vol. xlviii. p. 80.

[2] See Chap. V. pp. 79, 80.

[3] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. pp. 383, 384.

[4] See Chap. II. pp. 18–22.

and in other genera. Owing to the direct communication of the hydrospire-slits with the exterior there are no hydrospire-canals, pores, or spiracles.

From an examination of the British Codasters we can confirm the description of the ambulacra given by Billings. As there are no hydrospire-canals, there are no pores; and we doubt whether outer side plates are present in all the species. The outline of the ambulacra varies but little. They are lanceolate in the British species (Pl. XIII. figs. 1, 4), narrow and linear in *C. Americanus*[1], narrow in *C. Whitei*[2], and slightly petaloid in *C. Hindei*[3] (Pl. XII. fig. 4). The side plates do not cover the lancet-plate entirely, but rest on its sides, leaving about a third of its width uncovered. The sides of the lancet-plate are always deeply impressed for the reception of the side plates (Pl. XIII. figs. 8, 14). The latter vary in number according to the species; the British form possesses from six to ten on each side. *C. Whitei* has twenty-three or twenty-four, whilst in *C. pyramidatus* there are twenty-two. We have not been able to detect outer side plates in the British species, though between every two side plates there is a large socket for the reception of a so-called "pinnule." Lyon described the ambulacra of *C. alternatus* as "divided into four equal parts by three indented lines"[4]. Shumard described and figured the same thing in *C. pyramidatus*, and the structure of our *C. Hindei*[5] is identical (Pl. XII. fig. 4). The middle one of the three indented lines is the ambulacral groove, the two lateral ones bounding the side plates, which here lie upon, and almost entirely conceal, the lancet-plate. The outer side plates are placed outside the lateral "indented lines," and project somewhat upwards. The number of hydrospires varies in different species. In McCoy's *C. trilobatus* there are as many as ten exposed in each triangular area, or sometimes nine exposed and one partly concealed under the side of the adjacent ambulacrum (Pl. XIII. fig. 8). In other varieties of this species we meet with all the intermediate numbers of grooves or slits, from two to seven or eight, but always one, and sometimes one and a half are concealed (Pl. XIII. figs. 1, 4, 9, 11; Pl. XVI. fig. 2). The hydrospire-slits in *C. pyramidatus* are six or eight in number (Pl. XII. fig. 1), and there are seven or more in *C. alternatus*, var. *elongatus*, Wachsmuth, var. (Pl. X. fig. 19). Lastly, in *C. Hindei* there are seven apertures on each half of the anterior interradial spaces, one of which is more or less covered by the edge of the ambulacrum (Pl. XII. fig. 4). The interradial or oral ridges present some marked peculiarities, and the outline of the summit depends very considerably upon the flatness or the arched character of the deltoid plates which bear these ridges. In *C. pyramidatus* they are tolerably flat, broad, and

[1] Shumard, Trans. St. Louis Acad. Sci. 1858, vol. i. no. 2, p. 239.

[2] Boston Journ. Nat. Hist. 1861, vol. vii. no. 2, p. 327.

[3] Shumard, Trans. St. Louis Acad. Sci. 1858, vol. i. no. 2, p. 238.

[4] D. D. Owen's 3rd Report Geol. Survey Kentucky, 1857, p. 494.

[5] Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 235.

lanceolate (Pl. XII. fig. 1); sharp in *C. Whitei*, and barely separating the slits of adjacent interradii at their outer extremities. They become wider, however, towards the mouth, and their proximal ends in this species, and in *C. alternatus*, var. *elongatus*, bear small tubercles (Pl. X. fig. 19). In the latter form the oral ridges project somewhat above the general summit and slope inwards (Pl. X. fig. 20); but in *C. pyramidatus* they are inclined outwards, and to a certain extent also in *C. Hindei* (Pl. XII. figs. 2, 5). In the British *C. trilobatus* they are to all intents and purposes flat (Pl. XIII. figs. 1, 4). The radial sinuses are short in all the species. The anus is either more or less rhombic, as in *C. pyramidatus* (Pl. XII. fig. 1) and *C. trilobatus* (Pl. XIII. figs. 1, 4), or ovate, as in *C. alternatus*, var. *elongatus* (Pl. X. fig. 19). *Codaster* is closely allied to *Phænoschisma* in the exposure of the hydrospire-slits on the surface of the calyx, and in the absence of definite spiracles; but in the latter genus the anal interradius is occupied by hydrospires (Pl. XIV. figs. 5, 11), and the outline of the calyx in the two genera is often quite different.

Codaster has no connection whatever with *Stephanocrinus*, the peculiar characters of the latter type placing it quite apart from this and from other genera, especially as it is now known not to be a Blastoid at all; and we most emphatically protest against the statement of Prof. James Hall that "there are no differences which appear to be of generic importance between *Stephanocrinus* and *Codaster*"[1]. Such a belief could only have arisen from a total misapprehension of the structure of the latter genus.

Amongst the synonyms of *Codaster*, Dr. Bronn[2] in 1860 placed "*Astrocrinites*, Cumb. (non Austin)," but after much patient research we are quite unable to decide to what genus of Cumberland's Dr. Bronn referred. Cumberland certainly never described an "*Astrocrinites*." The genus *Heteroschisma* has been recently proposed[3] by Mr. C. Wachsmuth for the reception of three species which appear to him to differ from *Codaster* in the relation of the hydrospires to the deltoid plates. The species in question are said to have relatively small deltoids like *Phænoschisma*, while resembling *Codaster* in the absence of hydrospires from the anal interradius. The differences between the deltoids of *Codaster* and those of *Heteroschisma*, as described by Wachsmuth, are so great that were we convinced of their existence, we should be compelled to place *Heteroschisma* in a separate family by itself[4]. We find, however, not only that the deltoids of *C. pyramidatus*, Shum., and *C. Hindei*, nobis, are essentially similar to those of the type *C. trilobatus*, McCoy (Pl. XII. figs. 1–6; Pl. XIII. figs. 1, 4, 8), but that the same is true of the variety of *Codaster* (*Heteroschisma*) *alternatus*, Lyon, which is termed *elongatus* by Mr. Wachsmuth (Pl. X. figs. 19, 20), and also of Mr. Wachsmuth's type *Heteroschisma gracile* (Pl. XVI.

[1] Collett's 11th Ann. Report, Dept. Geol. & Nat. Hist. Indiana for 1881 [1882], p. 280.

[2] Klassen und Ordn. Thier-Reichs, 1860, Bd. ii. p. 189.

[3] Report Geol. Survey Illinois, 1883, vol. vii. p. 352.

[4] See *antea*, pp. 30–34.

fig. 1). Thus then we believe that the principal character on which *Heteroschisma* was established has no existence in fact. The only point in which there is any difference between *Heteroschisma*, as typified by *H. gracile*, Wachsmuth, and an ordinary *Codaster* is altogether of minor importance. Mr. Wachsmuth says that the side plates of the former meet the sides of the sinuses, though only "rarely" so in *H. gracile*[1].

We think that this may perhaps be the case, though we are by no means convinced that it is so. It is possibly due to the greater depth of the radial sinuses and their consequent diminution in width. We have noted what appear to be precisely similar differences amongst the various species of *Phænoschisma*. Under these circumstances we feel with great regret that we cannot accept *Heteroschisma* as a valid genus, but must simply look upon it as a synonym of *Codaster*.

Codaster was established by McCoy as a Blastoid, but Mr. Rofe[2] regarded it as a connecting link between the Crinoidea and Cystidea, *Pentremites* being more closely allied to the former, and *Codaster* to the latter. On the other hand, Billings[3] definitely referred it to the Cystidea, because there is no connection between its hydrospires and the cavities of the pinnulæ borne on the ambulacra, such as he assumed to exist in *Pentremites*. We cannot learn that any other palæontologist but Prof. K. Zittel[4] has definitely adopted this view, in which we certainly do not agree. If *Codaster* be a Cystid, so are *Orophocrinus* and *Phænoschisma*, which are also devoid of ambulacral pores. But *Codaster* is a true Blastoid in every respect; and we think that Billings was led to this erroneous conception by his not having emancipated himself from the old doctrine that the cavities of the pinnulæ and hydrospires of a Blastoid are directly connected by the ambulacral pores. Neither *Codaster*, *Orophocrinus*, nor *Phænoschisma* has any such pores, but the relations between them and the remaining Blastoids are so close that there can be no question of their systematic position, while Billings's theory is now abandoned by all the more prominent writers on the Blastoidea.

Species. After mature consideration we are prepared to admit five, or perhaps nine, species of *Codaster*, though not more, on account of the indefinite manner in which certain so-called *Codasters* have been described and figured. In Britain we possess only one, *C. trilobatus*, McCoy, but it presents several varieties (Pl. XIII.). The American species differ from the British type in possessing a more elongate form, greater convexity of summit, a narrower base, and more complex ambulacra (Pl. XII. figs. 1–6). Four of these are well defined, viz. *C. alternatus*, *C. gracile*, *C. Hindei*, and *C. pyramidatus*. Shumard described another species together with the last named as *C. Americanus*, but said that it was "very similar to *C. pyramidatus*, of

[1] Report Geol. Survey Illinois, 1883, vol. vii. p. 356.
[2] Geol. Mag. 1865, vol. ii. p. 251.
[3] American Journ. Sci. 1869, vol. xlviii. p. 80.
[4] Handb. Pal. 1879, 1 Bd. Lief. 3, p. 424.

which it may be merely a strongly marked variety;" and from his subsequent remarks on the subject[1], we are inclined to agree with the latter view. *Codaster Whitei*, Hall, is another doubtful species, as nothing is known of the condition of its anal interradius; but the ambulacra of a crushed specimen in Mr. Wachsmuth's collection seem to be those of *Codaster* rather than of *Phænoschisma.* The general appearance of *Codaster pulchellus*, Miller & Dyer, as shown in Hall's figures[2], leads us to think that its generic name is rightly given, though we totally disagree with Hall's statement that this species "presents all the essential features" of *Stephanocrinus.* On the other hand, *Codaster gratiosus*, Miller, was described from an internal cast[3], and there is no mention of any hydrospire-slits, which would have certainly been traceable on the cast if it really belonged to *Codaster.* We have already pointed out[4] that *C. pentalobus*, Hall, probably belongs to the *Troostoblastidæ.* On the other hand, we have little doubt that the *Pentremites subtruncatus* of Hall[5], which he described as belonging "to the same type of form" as *P.* (i. e. *Troostocrinus*) *Reinwardti*, is a *Codaster* or *Phænoschisma*, probably the former, so far as we can judge from the outline of its calyx; and we are glad to find that a similar view has been taken by Wachsmuth[6].

The species of *Codaster* are therefore as follows:—

Codaster alternatus, Lyon. Upper Helderberg Group, Lower Devonian; Kentucky. Hamilton Group, Upper Devonian; Kentucky (*fide* Wachsmuth).

Codaster alternatus, var. *elongatus*, Wachsmuth, var. Hamilton Group, Upper Devonian; Kentucky.

Codaster gracilis, Wachsmuth, sp. Hamilton Group, Upper Devonian; Michigan.

Codaster Hindei[7], E. & C. Hamilton Group, Upper Devonian; Ontario.

Codaster pyramidatus, Shumard. Upper Helderberg Group, Lower Devonian; Ohio, Kentucky, New York State.

Codaster trilobatus, McCoy. Carboniferous Limestone; Lancashire and Yorkshire.

Codaster trilobatus, var. *acutus*, McCoy, var. Carboniferous Limestone; Lancashire and Yorkshire.

[1] Trans. St. Louis Acad. Sci. 1858, vol. i. no. 2, p. 239.

[2] Collett's 11th Ann. Report, Dept. Geol. & Nat. Hist. Indiana for 1881 [1882], p. 280, pl. 15. figs. 8–10.

[3] Journ. Cincinn. Soc. Nat. Hist. 1880, vol. ii. no. 4, p. 257, pl. 15. fig. 5.

[4] *Antea*, pp. 129, 198.

[5] Iowa Geol. Report, 1858, vol. i. pt. ii. p. 485, pl. I. fig. 4 (*non* pl. II. fig. 3).

[6] Report Geol. Survey Illinois, 1883, vol. vii. p. 357.

[7] Possibly identical with *C. Canadensis*, Billings, MS.

Doubtful Species.

Codaster Americanus, Shumard. Upper Helderberg Group, Lower Devonian; Kentucky.

Codaster pulchellus, Miller & Dyer. Niagara Group, Upper Silurian; Indiana.

Pentremites subtruncatus, Hall. Hamilton Group, Upper Devonian; Iowa.

Codaster Whitei, Hall. Burlington Limestone, Subcarboniferous; Iowa.

Distribution. If *Codaster pulchellus*, Miller & Dyer, from the Niagara Group of Indiana be rightly so named, this genus has the most extended geological range of all the Blastoidea. Commencing in the Upper Silurian of America, it is well represented both in the Upper Helderberg and in the Hamilton Group of the Devonian Period, especially the latter; while the doubtful *C. Whitei*, Hall, occurs in the transition-bed between the Upper Burlington and the Keokuk Limestones of the American Subcarboniferous. The type species (*C. trilobatus*) is fairly abundant in the Carboniferous Limestone of Lancashire and Yorkshire, and may be considered, we suppose, as the last survivor of the genus.

Type. Codaster trilobatus, McCoy.

1. SPECIES FROM THE DEVONIAN.

a. Obpyriform Species.

CODASTER PYRAMIDATUS, *B. F. Shumard.*

(Pl. XII. figs. 1–3.)

Codaster alternatus, Lyon (*fide* Wachsmuth[1]), Owen's 3rd Report Geol. Survey Kentucky, 1857, p. 493, t. 5. f. 3, *b* (excl. f. 3, *a*).

Codaster pyramidatus, Shumard, Trans. St. Louis Acad. Sci. 1858, vol. i. no. 2, pp. 238 & 247, t. 9. f. 1, *a–e*, *ibid.* 1865, vol. ii. no. 2, p. 359.

Codaster pyramidatus, Hall, Fifteenth Ann. Report New York State Cab. Nat. Hist. 1862, p. 152, t. 1. f. 12 & 13.

Sp. Char. Calyx obpyramidal, tapering rapidly to the small attenuated base; summit moderately convex; section distinctly pentagonal; periphery at the distal ends of the ambulacra, near the summit. Basal plates forming a small, almost round, attenuated cup, less than one third the height of the calyx, terminating below in a triangular surface, slightly concave. Radial plates elongate, longer than wide, gradually expanding in width upwards; bodies almost double the length of the limbs, each marked by a rounded triangular ridge which narrows gradually upwards till it reaches the inconspicuous lip; interradial sutures placed in depressions; sinuses triangular, short, and wide, with inwardly bevelled or sloping sides;

[1] Report Geol. Survey Illinois, 1883, vol. vii. p. 354 (note).

lateral portions of the plates with an obliquely flattened band, limited or marked off by a fine hair-like ridge. Deltoid plates triangular, short, and broad, with constricted apices, and the centre of each plate occupied by a flattened linear petaloid space; posterior deltoid almost entirely occupied by the anus. Ambulacra elongately petaloid, somewhat arched, projecting above the margins of the sinuses, and even above the surface of the summit; the food-groove strongly marked; side plates twenty-two. Hydrospire-slits seven or eight, one being always partly concealed. Mouth very distinctly pentagonal. Anus rhombic-triangular, and very large. Column circular; canal minute. Ornament of very fine striæ parallel to the outline of the plates, those on the marginal bands of the radial plates being particularly distinct.

Remarks. This species does not require comparison at all with the British *C. trilobatus*. So far as can be judged from the measurements of the other Carboniferous form, *C. Whitei*, Hall, in the absence of a figure, the two appear to be quite distinct. *C. pyramidatus* may be distinguished from *C. Hindei* by its more attenuated base, convex summit, arched and prominent ambulacra, and the marginal bands on the radial plates. Dr. B. F. Shumard describes the radials of *C. Americanus* as quite devoid of these obliquely flattened portions, but we doubt whether it is anything more than what he called "a strongly marked variety;" and the same remark applies to the specimen figured by Hall [1] as *C. pyramidatus*, "or a closely allied species." According to Mr. C. Wachsmuth [2] the *Codaster alternatus* of Lyon [3] was founded on more than one species. One of these [4] he considers to be the form afterwards described by Shumard as *C. pyramidatus*, the present species, and would retain this name for it. The other [5] Mr. Wachsmuth believes to represent a distinct genus, for which he has proposed the name *Heteroschisma*, retaining Lyon's trivial name *alternatus* for the species. We are inclined to agree with Mr. Wachsmuth that the two forms are distinct specifically, but we differ from him on the generic question, as already pointed out [6]; for we regard both the species figured by Lyon as true Codasters. The second one, *Codaster alternatus* (Pl. X. figs. 19, 20), differs from the first, *C. pyramidatus*, Shum. (Pl. XII. figs. 1–3), in possessing a concave or inwardly excavated summit, in the absence of the flattened bands around the interradial sutures, and in other minor points. Mr. Wachsmuth believes that this specimen, which we have figured on Pl. X., is a varietal form of *C. alternatus*, which he has proposed to call *C. elongatus*, but as it is the only example of Lyon's species which we have seen we can offer no opinion upon this point.

Localities and Horizon. Columbus, Ohio: Corniferous Limestone, Lower Devonian

[1] Fifteenth Ann. Report New York State Cab. Nat. Hist. 1862, p. 152, pl. 1. figs. 12, 13.

[2] Report Geol. Survey Illinois, 1883, vol. vii. p. 354 (note).

[3] D. D. Owen's 3rd Report Geol. Survey Kentucky, 1857, p. 493.

[4] *Ibid.* pl. 5. f. 3, *b*. [5] *Ibid.* f. 3, *a*. [6] *Antea*, pp. 30–34, & 263, 264.

(Presented by Prof. H. A. Nicholson, M.D., &c.). [Kentucky, *fide* Wachsmuth; New York State, *fide* Hall: Upper Helderberg Limestone, Lower Devonian.]

2. SPECIES FROM THE CARBONIFEROUS.

b. Ovate Species.

CODASTER TRILOBATUS, *McCoy.*

(Pl. XII. fig. 8; Pl. XIII. figs. 1–15; Pl. XVIII. fig. 1.)

Codaster trilobatus, McCoy, Ann. & Mag. Nat. Hist. 1849, vol. iii. p. 251.
Codaster trilobatus, McCoy, Brit. Pal. Foss. 1851, fasc. 1, p. 123, t. 3 D. f. 8 & 8[a] (*Codonaster* in expl. of plate).
Codonaster trilobatus, Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 386, t. 8. f. 3, *a* & *b*.
Codonaster trilobatus, Dujardin & Hupé, Hist. Nat. Zooph. Échinod. 1862, p. 102.
Codaster trilobatus, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 235.

Sp. Char. Calyx ovate or cup-shaped, formed by thick, strong plates, and tapering very slowly towards the base, which is always more or less trilobate, one extreme assuming the form of a flattened tripod, whilst in another these divisions do not descend low enough to become marked, and the base is more acute; summit truncated, and either flat or slightly convex; section pentagonal, the sides of the calyx flat, or a little convex; periphery at about one half the height of the radial plates. Basal plates obtusely lobate towards their lower margins, forming, when in union, a broad expanded cup; interradial sutures placed in depressions. Radial plates longer than wide, the limbs bent inwards horizontally to form the flat summit; interradial sutures in slight depressions; sinuses narrow and very short, and wholly excavated out of the summit portions of the plates. Deltoid plates diamond- or lozenge-shaped; oral ridges strong, and convex or subcristiform. Ambulacra petaloid, short, projecting above the radio-deltoid margins; food-grooves wide and deep, excavated in the lancet-plates for nearly the whole length of the ambulacra; sides of the lancet-plates deeply impressed for the reception of the side plates, which are eight to ten in number (sometimes meeting in the middle line at the distal ends of the ambulacra). Six to ten hydrospire-slits, one of them usually covered by the ambulacrum; hydrospire-tubes long and much compressed; sacs hardly differentiated from them. Column round, stem-joints small. Ornament of fine raised subimbricating lines, parallel to the margins of the plates.

Remarks. With the exception of the original description by McCoy, and that subsequently given by Roemer, little appears to have been written about either *C. trilobatus* or its variety *acutus*. Although a number of specimens are contained in the "Gilbertson Collection," which illustrates the second part of the 'Illustrations of the Geology of Yorkshire,' by the late Prof. John Phillips, that author does not

in any way refer to a form resembling *Codaster*, unless it be the "new genus" from Bolland, referred to under the Echinoidea[1]. We are inclined to this view, from the context of certain labels accompanying the specimens. It is not impossible that the figure given by the late Mr. Billings[2] as that of *Codaster acutus*, McCoy, is in reality a representation of the present species, judging from the number of hydrospire-slits in each interradius.

The hydrospire-slits, as a rule, are eight in number (Pl. XIII. fig. 10), and some large specimens possess ten (Pl. XIII. fig. 8), but we have not seen examples with more. On the other hand, we have some specimens possessing all the characters of *C. trilobatus*, in which there are only six hydrospire-slits in each interradius.

The flattened summit of *C. trilobatus* (Pl. XIII. figs. 1, 3, 4, 9–12) at once distinguishes it from all the American species of the genus, in each of which there is a distinct radial sinus so that the dorsal surface of the radials is divisible into body and limbs (Pl. XII. figs. 2, 3, 5, 6), whereas in *C. trilobatus* there are really no true limbs at all (Pl. XIII. figs. 3, 8–12, 15). This is especially the case in the only species from the American Carboniferous, *C. Whitei*, Hall.

The ornamentation of the calyx was not described by McCoy, and from the peculiar state of preservation of the large number of specimens is seldom visible. The radial plates are concentrically imbricate-striate, but on the basal plates the striæ following the margins of the plates become festoon-shaped (Pl. XIII. figs. 2, 3, 13).

Localities and Horizon. Bolland, Lancashire; Settle, Yorkshire: Carboniferous Limestone. (Presented by the late J. Rofe, Esq., F.G.S.)

CODASTER TRILOBATUS, *var.* ACUTUS, *McCoy*, var.

(Pl. XIII. figs. 9–12, 15; Pl. XVI. fig. 2.)

Pentremites? astraformis, T. & T. Austin (MS.), Ann. & Mag. Nat. Hist. 1842, vol. x. p. 111.
Pentremites pentagonalis, Forbes, Mem. Geol. Survey Gt. Brit. 1848, vol. ii. pt. 2, p. 529, f. *a*.
Codaster acutus, McCoy, Ann. & Mag. Nat. Hist. 1849, vol. iii. p. 251.
Codaster acutus, McCoy, Brit. Pal. Foss. 1851, fasc. 1, p. 123, t. 3 D. f. 7 (*Codonaster* in expl. of plate).
Codonaster acutus, Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 385, t. 8. f. 2, *a–d* (excl. syn. *Astrocrinites*).
Codonaster acutus, Roemer, Bronn's Lethæa Geogn., Dritte Aufl. 1852, Theil 2, p. 285, t. 4'. f. 11, *a–c*.
Codonaster acutus, Bronn, Klassen und Ordn. Thier-Reichs, 1860, Bd. ii. t. 23. f. 6, *a–c*.
Codonaster acutus, Dujardin & Hupé, Hist. Nat. Zooph. Échinod. 1862, p. 102, t. 2. f. 17.
Codaster acutus, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 235.

[1] *Op. cit.* p. 208.

[2] American Journ. Sci. 1869, vol. xlviii. p. 79, f. 8; Canadian Nat. & Geol. 1869, vol. iv. p. 288, f. 8; Ann. & Mag. Nat. Hist. 1870, vol. v. p. 261, f. 8. We suspect that this figure was copied from Roemer.

Remarks. We quite agree with Prof. F. Roemer and with Messrs. Dujardin and Hupé that McCoy's *Codaster acutus* is nothing more than a variety of his other species. In fact we go further, and believe it to be only the young condition of *C. trilobatus.* According to usual custom this, being the first form described by McCoy, ought to be considered as the type of the genus *Codaster.* But to accept a young and immature stage of any species as a generic type when we are in possession of the perfect and mature form would be highly unphilosophical, and lead to endless confusion.

The specimens we desire to retain under the varietal name *acutus* differ from *C. trilobatus* in possessing a smaller calyx, a more acute and less trilobed base, with a smaller number of side plates and hydrospires. The latter vary according to the age of the individual from two to five in number, and in exceptional cases there are six (Pl. XIII. figs. 4, 9–12). We have seen examples with both the intermediate numbers, three and four. In the very young state (Pl. XVI. fig. 2) the ambulacra occupy a relatively much larger portion of the summit than they do in the more advanced condition. With growth the ambulacra become narrower and longer, and the interradial spaces wider, the hydrospires increasing in number accordingly. The sharper and longer proportions of the calyx in this variety, or young condition, whichever it may be called, is quite in accordance with the observations of Mr. Wachsmuth on calycular growth amongst the Blastoidea [1], as we have undoubted evidence in the series of specimens before us of the rapid lateral expansion or widening out of the calyx as compared with its longitudinal growth.

We believe, guided by some old labels attached to specimens, that it was to this form of *Codaster* that Messrs. Austin contemplated applying their name *Pentremites*? *astraformis.* There is also little doubt that Prof. Roemer was correct in referring the figure of *Pentremites pentagonalis*, Forbes, to this variety. On the other hand, we believe that our eminent friend was misled in giving on de Verneuil's authority *Astrocrinites,* Cumberland, as another synonym of *Codaster acutus*, for we have no evidence that Cumberland even proposed this name for any genus of Pelmatozoa.

Localities and Horizon. Bolland, Lancashire; Settle, Yorkshire: Carboniferous Limestone. (Presented by the late J. Rofe, Esq., F.G.S.)

Genus PHÆNOSCHISMA, E. & C., 1882.

Pentremitidea, Carpenter (pars), Report Brit. Assoc. for 1881 [1882], pt. 2, p. 634.

Phænoschisma, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 226.

Gen. Char. Calyx elongately clavate, or obpyramidal, with deeply excavated summit. Basal plates forming an elongated cup. Radial plates each bear three more or less distinct folds diverging from the lip; the two contiguous limbs forming

[1] Report Geol. Survey Illinois, 1883, vol. vii. pp. 349, 350.

the anal interradius are more or less abortive; sinuses wide and deep, generally with relatively steep sides. Deltoid plates small, and confined to the summit, where they are either horizontally placed or inclined inwards. Lancet-plates concealed by the side plates (in all but one species); outer side plates very small. Spiracles rarely present. Ten groups of hydrospires, which are pendent, and open externally by a series of elongated slits with intervening ridges, distributed in subparallel series on the sloping sides of all the radial sinuses. They are only partially covered by the ambulacral plates, their distal ends (or even the entire length of some) being visible on the sides of the sinuses. Column large as compared with the size of the calyx.

History. We established the genus *Phœnoschisma* in 1882 for a small number of interesting species previously included in *Pentremites*. The late Mr. E. Billings, in a remarkable article "On the Structure of the Crinoidea, Cystidea, and Blastoidea,"[1] referred as follows to the peculiar characters of *Pentremites caryophyllatus*, de Koninck (Pl. XIV. figs. 3, 4):—"The ends of the fissures of the hydrospires are seen along the sides of the angular ridges, which extend from the apices of the pyramids to the angles between the arms. I do not think that such species can be referred to *Pentremites*; and if I had specimens before me instead of figures only, I would most probably institute a new genus for their reception." As we entirely agree with Mr. Billings's remarks, it has afforded us much pleasure to adopt and extend his suggestion by proposing the name *Phœnoschisma* for Blastoids possessing these characters.

Remarks. The appearance of some (often many) of the hydrospire-slits externally is a very striking feature in *Phœnoschisma* and distinguishes its species at once from the other Blastoids which they may resemble in external form. Thus, for example, *P. Archiaci* and some species of *Pentremitidea* are not at all unlike in side view (Pl. IV. fig. 11; Pl. XII. fig. 10; Pl. XIV. fig. 13). But the summit-characters of the former type (Pl. XIV. figs. 5–7) are altogether different from those of the *Pentremitidæ*, and indicate its relationship to *Codaster*. The same may be said of *P. caryophyllatum* (Pl. XIV. figs. 1–4), entire examples of which might readily be mistaken for aberrant forms of *Pentremites*, as is well seen in Roemer's figure[2]. No one, however, could possibly say this of *P. nobile* or of *P. Verneuili* (Pl. XI. figs. 1–6), types that are obviously very closely allied to those species of *Codaster* (Pl. X. figs. 19, 20; Pl. XII. figs. 1–6) which have the radial sinuses more deeply excavated than is the case in the British *C. trilobatus* (Pl. XIII. figs. 1–4).

The presence of hydrospires in the anal interradius sharply distinguishes *Phœnoschisma* from *Codaster*, and so renders the former a less aberrant type than it would otherwise be (Pl. XI. fig. 6; Pl. XIV. figs. 5, 11). Its deltoid plates are limited to

[1] American Journ. Sci. 1869, vol. xlviii. p. 80; Canad. Nat. & Geol. 1869, vol. iv. p. 288; Ann. & Mag. Nat. Hist. 1870, vol. v. p. 262.

[2] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. Taf. iv. f. 16.

the summit, just like those of *Codaster*, the radio-deltoid sutures descending the sides of the sinuses and meeting the ambulacra (Pl. XI. figs. 1–3, 5, 6 ; Pl. XIV. figs. 9, 11, 12). These are extremely variable in their character, being sometimes narrow and linear as in *P. nobile* and *P. Verneuili* (Pl. XI. fig. 4 ; Pl. XIV. fig. 9), and sometimes so broad as to conceal the greater part of the hydrospire-slits as in *P. caryophyllatum*, *P. Archiaci*, and *P. acutum* (Pl. XIV. figs. 3, 4, 6, 11). The proximal side plates of these three species project considerably beyond the edges of the lancet-plate and so bridge over the lower part of the radial sinus, thus converting it into a canal on either side of the lancet-plate; and there are minute spiracular openings round the mouth by which these imperfect hydrospire-canals communicate with the exterior, though they can also do so through the uncovered ends of the hydrospire-slits. In *P. caryophyllatum* and *P. Archiaci* these are the distal ends (Pl. XIV. figs. 3, 4, 6), but in *P. acutum*, so far as we can make out, it is the distal ends of the slits which are covered by the ambulacra (Pl. XIV. fig. 11). Our best example of this species approaches rather closely to *Cryptoschisma*, as no slits are visible at all in one interradius, though in other parts of the calyx one may be seen above the ambulacrum. In *P. caryophyllatum* we often find one entire slit exposed, with the distal ends of four or five others (Pl. XIV. fig. 3), while in *P. Archiaci* two slits are completely visible and four others partially so (Pl. XIV. fig. 6). In the species with narrow ambulacra, however (Pl. XI. figs. 1–6), the great majority of the slits are altogether uncovered.

All the species but *P. caryophyllatum* have a narrow lancet-plate, which is completely concealed by the side plates (Pl. XI. figs. 3, 4 ; Pl. XIV. figs. 5–7, 9, 11); but in this curious type they simply lie against the lancet-plate as in *Pentremites* and do not cover it at all (Pl. XIV. figs. 2, 3), so that in this respect it approaches *Cryptoschisma* more closely than *P. acutum* does.

The absence of the deltoids from the exterior of the calyx readily distinguishes *Phænoschisma* from *Orophocrinus*, some forms of which (Pl. XIV. figs. 14, 17) approach it rather closely in other respects. The anal aperture varies in its character according to the species. For instance, in *P. Archiaci* the contiguous limbs of adjacent radials forming the anal interradius are shortened and truncated, so as partially to surround the anus (Pl. XIV. fig. 5). In *P. acutum*, Phill., sp., on the other hand, the cristiform aspect of the other interradii is in no way altered in the azygos interradius, and the surface of the anal deltoid is hollowed out for the partial reception of the aperture (Pl. XIV. fig. 11).

Species. The following is a list of the species which we refer to *Phænoschisma* :—

Pentatrematites acuta, G. B. Sowerby. Carboniferous Limestone ; Lancashire.
Phænoschisma Archiaci, E. & C. Lower Devonian ; Leon and Asturias, Spain.
Phænoschisma Benniei, sp. nov. Lower Carboniferous Limestone ; Scotland.

Pentremites caryophyllatus, de Koninck. Carboniferous Limestone; Belgium.
?*Pentremites* (*Codaster*?) *Kentuckyensis*, Shumard. Subcarboniferous; Kentucky.
Phænoschisma nobile, E. & C. Lower Devonian; Leon, Spain.
Phænoschisma Verneuili, E. & C. Lower Devonian; Leon & Asturias, Spain.

We have placed *Pentremites Kentuckyensis*, Shumard[1], in *Phænoschisma* rather than in *Codaster*, to which he subsequently referred it[2], on account of the narrow and linear form of the ambulacra, which are closely similar to those of *P. nobile* and *P. Verneuili* (Pl. XI. fig. 4; Pl. XIV. fig. 9), and somewhat different from those of *Codaster*.

Mr. Wachsmuth has also sent us two species from New Mexico which he will himself describe eventually, so that the occurrence of the genus in America rests on other evidence than that of Shumard's *Pentremites Kentuckyensis*.

Distribution. The earliest known species of *Phænoschisma* are *P. Archiaci* and *P. Verneuili*, which occur in the Calcaire de Ferroñes in the Lower Devonian of Spain. Like *Pentremitidea Paillettei*, they both pass up into the Calcaire d'Arnao, where *P. nobile* also occurs. The Carboniferous Limestone Series of England, Scotland, and Belgium, each contains one species, and there would appear to be three others in rocks of corresponding age in America, so that the genus has a comparatively extensive range, both in space and in time.

Type. *Pentatrematites acuta*, G. B. Sby.

1. SPECIES FROM THE DEVONIAN.

PHÆNOSCHISMA VERNEUILI, *E. & C.*

(Pl. X. fig. 18; Pl. XI. figs. 5, 6; Pl. XIV. figs. 8, 9.)

Phænoschisma Verneuili, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 230.

Sp. Char. Calyx elongately pyramidal; base sharp and pointed; summit hollow, excavated in the direction of the rays; the ambulacra are separated by strong interradial processes, each of which is formed by the union of the adjacent limbs of two contiguous radials; section distinctly pentagonal at the distal ends of the ambulacra. Basal plates forming an elongated cup, about two thirds the length of the radials, and a little longer than the bodies of those plates. Radial plates large and arched; limbs long and projecting above the summit, but those of the anal interradius are flattened or depressed; sinuses very wide and deep, with high sloping sides; lips prominent, with three folds diverging downwards from each. The anal deltoid is diamond-shaped. Ambulacra linear, scarcely increasing in width; lancet-plate narrow, entirely concealed; side plates from twenty to twenty-five, apparently oblong;

[1] Trans. St. Louis Acad. Sci. 1858, vol. i. no. 2, p. 239, pl. ix. fig. 5.
[2] *Ibid.* 1865, vol. ii. no. 2, p. 359.

outer side plates very small and triangular. Hydrospire-slits from twelve to eighteen, crowded together. Mouth small; anus roundly triangular. Surface ornamented by sharp striæ parallel to the margins of the plates; a distinct border follows the margin of each radial plate, defined by a faint groove.

Remarks. Phænoschisma Verneuili needs no comparison with other species of the genus, except with *P. acutum* (Pl. XIV. fig. 10), from which it differs in size, in the elevated nature of its interradii, and in its greater number of hydrospire-slits. As regards form, *P. Verneuili* represents one extreme modification of the genus, and *P. caryophyllatum* another (Pl XIV. fig. 4).

Localities and Horizon. Ferroñes, Province of Asturias, Spain: Calcaire de Ferroñes, Lower Devonian. [Also at Colle, near Sabero, Province of Leon: Calcaire d'Arnao.]

PHÆNOSCHISMA ARCHIACI, *E. & C.*

(Pl. XI. fig. 7; Pl. XII. fig. 10; Pl. XIV. figs. 5–7; Pl. XVII. fig. 15.)

Pentremitidea Pailleti (pars), Carpenter (non Verneuil), Report, Brit. Assoc. for 1881 [1882], pt. 2, p. 634.

Phænoschisma Archiaci, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 230.

Sp. Char. Calyx clavate, becoming more pentalobate with age; sides concave, not straight; base long and often sharp; summit truncate. Basal plates very long and slender, longer than the radials, and expanding very gradually into a small cup, the surfaces ornamented with concentric striæ which have two different directions, while the lower part of each plate bears a strong median ridge. Radial plates small, lobate about the lips, projecting somewhat upward, and obliquely truncate on their upper margins; those of the anal interradius are a little flattened; surface somewhat angular in the middle line from the lips down to the basiradial suture; sinuses short, having a radial angle of about 130°, and somewhat petaloid. Deltoid plates much overlapped by the radials and confined to the immediate neighbourhood of the mouth. Ambulacra short, and a little petaloid; lancet-plates narrow, deeply triangular in section; side plates few, six to eight or nine, large and oblong; outer side plates triangular, and very small. Hydrospire-slits six to eight on each side of an ambulacrum, the innermost one covered by the lancet-plate, a limited number only being exposed when the side plates are in position. Hydrospires in the form of long slender sacs. Mouth small. Anus roundly triangular. Column composed of round, apparently biconcave, and for the size of the calyx, thick joints; canal very minute. Ornament of concentric striæ.

Remarks. This is a common species and has been very generally confounded with *Pentremitidea Paillettei*, several examples of it having been found under this name in the National Collection mixed up with others which are really referable to that species. It is, however, an entirely different type. For apart from the direct exposure of some of the hydrospire-slits, its ambulacra are altogether different from

those of *P. Paillettei* (compare Pl. IV. figs. 8, 10, and Pl. XIV. fig. 6), which has smaller and more numerous side plates.

P. Archiaci does not possess the elevated interradial processes of *P. Verneuili* (Pl. XI. fig. 5), and is thereby distinguished from it, apart from their differences in other characters. The outline of the calyx generally, the form of the anal interradius, and the characters of the ambulacra and hydrospire-slits separate it from *P. acutum* (Pl. XIV. fig. 10). It is also unlike *P. caryophyllatum* (Pl. XIV. figs. 1–4), but may be said to be a transitional form between this last and the two former species. There appears to be a good deal of individual variation in the relative length of the stem-like base of the calyx. The ornamentation of the basal plates is quite similar to that of *Pentremitidea Lusitanica* (Pl. IV. fig. 11), and might lead to a confusion of the two species should the generic characters not be properly attended to.

We have not been able to get a good view of the radio-deltoid sutures in any example of *P. Archiaci*; but the rubbed-down summit which is represented on Pl. XI. fig. 7 shows that the deltoids are really rather large plates, though much overlapped by the radial limbs. The few aborted hydrospires of the anal interradius (Pl. XIV. fig. 5) are not seen in this figure.

Localities and Horizon. Ferroñes, Province of Asturias, Spain: Calcaire de Ferroñes, Lower Devonian. Colle, near Sabero, Province of Leon: Calcaire d'Arnao, Lower Devonian (Presented by Dr. P. H. Carpenter, F.R.S.).

PHÆNOSCHISMA NOBILE, *E. & C.*

(Pl. XI. figs. 1–4.)

Phænoschisma nobile, E. & C., Ann. & Mag. Nat. Hist. 1883, vol. xi. p. 246.

Sp. Char. Calyx elongately ob-pyramidal, decreasing in width slowly, with sharp, strong, and prominent interradial processes, truncated and terminating but little above the level of the peristome; section obscurely pentagonal. Basal plates forming an obtusely conical cup. Radial plates very long and narrow, arched, the bodies and limbs being about equal in length, and the former bluntly angular in the middle line. The sinuses are exceedingly wide and deep, with high sloping sides, the edges of which are prominent and a little thickened; lips inconspicuous. Deltoid plates large, forming the summits of the interradial processes; anal deltoid truncated and excavated at its distal end. Ambulacra narrow, linear, of uniform width throughout; lancet-plates at the bottom of the sinuses, entirely concealed by the side plates, which are thirty or more in number, wedge-shaped in outline, horizontal in position at the proximal ends of the ambulacra, and becoming arched downwards distally. Outer side plates very small, placed at the extreme edges of the ambulacra, and standing almost vertically so as to fill in the notches between the outer ends of the side plates. Hydrospire-slits from twenty-five to thirty-five in number, occupying the whole of the steep and subimbricate sides of the sinuses, closely crowded

together. Mouth very small. Anus triangular pyriform, with a thickened edge. Ornament unknown. Column unknown.

Remarks. *P. nobile* is the largest species of the genus we have met with, reaching four cm. in height, and is intermediate in character between *P. Verneuili* and *P. acutum* (Pl. XIV. figs. 8–11). It may, however, be at once distinguished by the great number of its hydrospire-slits, which give to the sides of the sinuses quite a hackly appearance. *P. nobile* resembles the first of the above-named species in the form of its plates and ambulacra, and in the arrangement of the hydrospire-slits; but in addition to the character just mentioned, it differs in possessing a truncated summit (Pl. XI. fig. 1), for the crests of the deltoid plates do not slope downwards towards the peristome, as in *P. Verneuili* (Pl. XI. fig. 5). In this character, however, *P. nobile* resembles the much smaller *P. acutum* (Pl. XIV. fig. 10), though readily distinguishable from it by the form of its radial sinuses and by its narrow ambulacra. We believe that *P. nobile* presents the very largest development of the hydrospires which is possible in a Blastoid.

Locality and Horizon. Colle, near Sabero, Province of Leon, Spain: Calcaire d'Arnao, Lower Devonian. (Presented by Dr. P. H. Carpenter, F.R.S.)

2. SPECIES FROM THE CARBONIFEROUS.

PHÆNOSCHISMA ACUTUM, *G. B. Sowerby*, sp.

(Pl. XIV. figs. 10–12.)

Pentatrematites acuta, G. B. Sby., Zool. Journ. 1834, vol. v. no. 20, p. 456, t. 33. Suppl. f. 6 *a–c*.
Pentremites acutus, Phillips, Ill. Geol. York. pt. 2, 1836, p. 207, t. 3. f. 4–5*.
Pentatrematites acutus, Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 358.
Pentremites acutus, Dujardin & Hupé, Hist. Nat. Zooph. Échinod. 1862, p. 93.
Phænoschisma acutum, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 229.

Sp. Char. Calyx small, acutely pyramidal, rapidly tapering below; summit subtruncate; section pentagonal, with flat or straight, non-lobate sides; interradial processes truncated inwards, not projecting above the summit. Basal plates forming an elongated cup resembling a bouquet-holder, each plate being acutely angular in the middle line. Radial plates elongate, arched, the bodies angular in the middle line, but slightly longer than the limbs; sinuses wide and deep, with steep sides. Deltoid plates relatively large and rhombic, the posterior one simply pierced by the anus near its proximal end, but not otherwise modified. Ambulacra elongately petaloid; lancet-plate narrow, especially at its distal end, deeply excavated for the side plates; the latter are relatively large and oblong, or inclined to wedge-shaped; ambulacral groove deeply channelling the lancet-plate at its proximal end. Hydrospire-slits four or five, excavated in the substance of both radial and deltoid plates, usually only one completely exposed in each area when the side plates are in position; minute spiracles probably present at the central ends of the ambu-

lacra. Mouth small. Anus probably pyriform. Column and ornament not preserved.

Remarks. *P. acutum* is the smallest species of *Phænoschisma* but one with which we are acquainted. Irrespective of size it may be distinguished from *P. Verneuili* (Pl. XI. figs. 5, 6) by the truncated upper edges of the interradii, and by the smaller number of hydrospire-slits. The outline of the calyx generally, and the form of the anal interradius distinguish it from *P. Archiaci* (Pl. XII. fig. 10; Pl. XIV. figs. 5–7). One hydrospire-slit is usually visible for the greater part of its length, although it may occasionally be concealed (Pl. XIV. fig. 11). We have had the advantage of studying the original specimen, contained in the "Gilbertson Collection," which was used by the late Mr. G. B. Sowerby in his first description, and afterwards figured by Prof. J. Phillips in his 'Illustrations of the Geology of Yorkshire.'

Locality and Horizon. Bolland, Lancashire: Carboniferous Limestone.

PHÆNOSCHISMA CARYOPHYLLATUM, *de Koninck*, sp.

(Pl. XIV. figs. 1–4; Pl. XVII. fig. 16.)

Pentremites inflatus, de Koninck (non Sowerby), Rech. Anim. Foss. Terr. Carb. Belgique, 1842, p. 38.

Pentatrematites Orbignyanus, Roemer (non de Kon., sp.), Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 358, t. 7. f. 16 *a–c* (excl. syn.).

Pentremites caryophyllatus, de Kon. & le Hon, Mém. Acad. Roy. Belgique, 1854, tom. xxviii. Mém. 2, p. 197, t. 7. f. 3, *a–c*.

Pentremites caryophyllatus, Dujardin & Hupé, Hist. Nat. Zooph. Echinod. 1862, p. 93.

Pentremites caryophyllatus, Billings, American Journ. Sci. 1869, vol. xlviii. p. 79, f. 11.

Phænoschisma caryophyllatum, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 229.

Sp. Char. Calyx pyriform, much expanded above, and attenuating rapidly towards the base; summit more or less expanded and depressed; section almost circular; periphery almost equatorial but nearer the summit than the base. Basal plates forming a graceful, short, conical cup, about one third the entire height of the calyx. Radial plates oblong, much arched both transversely and longitudinally, barely twice the length of the basals; limbs long, strongly constructed, and not projecting above the summit; bodies concave in the middle line from the lips to the basiradial sutures; sinuses very wide and open, with moderately high sloping sides; lips very prominent and overhanging. Deltoid plates relatively small, their crests horizontal, or very slightly inclined outwards, but the anal deltoid deeply excavated along almost its whole length. Ambulacra broadly petaloid with the greatest width at the level of the radio-deltoid sutures; lancet-plates completely exposed; side plates oblong, scarcely bent down at all. Hydrospire-slits from five to seven, one always remaining uncovered, together with the distal ends of four or even five others. Spiracles present as small obliquely elongated apertures. Mouth small. Anus oblong. Ornament of fine thread-like lines parallel to the margins of the plates.

Remarks. This species was originally considered by Prof. de Koninck as identical

with *Pentatrematites inflata*, Sowerby [1], but Prof. F. Roemer, in his 'Monograph,' placed it as a synonym of de Koninck's other species *Pentremites Orbignyanus*. Messrs. de Koninck and Le Hon in their turn showed that both these references were wrong, and proposed for the species its present name.

Phænoschisma caryophyllatum is the abnormal species of the genus. It is shorter, rounded, and more depressed than any of the others, and the ambulacra are, to a great extent, petaloid (Pl. XIV. figs. 4, 5). For the side plates merely rest against the lancet-plate as in *Pentremites* (Pl. I.), and not on it as in *Phænoschisma Archiaci* (Pl. XIV. figs. 5–7).

In Roemer's figure of *P. caryophyllatum*, and again in those given by de Koninck and Le Hon and Billings, a very misleading feature is shown. The hydrospire-slits, instead of issuing from beneath the side plates outwards and downwards, are represented as coming from beneath them upwards and outwards, *i. e.* towards the radial centre. They are correctly drawn, however, in the side views, figured by both de Koninck and Roemer.

Locality and Horizon. Tournay, Belgium: Lower Carboniferous Limestone Shale.

PHÆNOSCHISMA BENNIEI, sp. nov.

(Pl. II. fig. 37; Pl. IV. figs. 5, 6.)

Pentremites, sp., Etheridge, Jr. (pars), Proc. Nat. Hist. Soc. Glasgow, 1881, vol. iv. pt. 2, p. 260, t. 5. f. 7.

Sp. Char. Calyx small, short, and bud-like; base very small, and cup-like; periphery at the radial lips, nearer the base than the summit. Basal plates very small, forming a low cup. Radial plates broadly oblong; bodies angular in the middle line, with two faint impressed lines passing obliquely downward from the lip, one on each side; limbs about equal to the bodies in length, parallel-sided, truncated above; sinuses wide, with moderately high inturned sides, and rim-like edges, lips pointed and projecting; interradial sutures in depressions. Deltoid plates small, triangular, and quite apical. Ambulacra long, narrow, and almost parallel-sided, tapering slowly, and situated low down in the sinuses; side plates oblong, with slit-like sockets; lancet-plates exposed only in the ambulacral grooves. Hydrospire-slits four on each side, wide and very apparent, two of them covered by the side plates. Ornament consists of microscopic lines arranged parallel to the margins of the plates.

Remarks. This little species is of the greatest interest both from the fact of its being the only regular Blastoid yet found in the Carboniferous rocks of Scotland, and from its generic relations.

The specimen originally figured by one of us was not in a sufficiently good state of preservation to exhibit some of its more essential points of structure. But other

[1] This is the *Orophocrinus verus*, figured on Pl. XV. figs. 1–5.

examples of the type which have now come to hand through the efforts of Mr. James Bennie have enabled us to determine its generic affinities. By means of careful manipulation we have succeeded in exposing hydrospire-slits on the sloping sides of the radial sinuses, the presence of which indicates that the species should be referred to our genus *Phænoschisma.* There are four slits on each side of a sinus, which are particularly well marked for so small an organism (Pl. II. fig. 37), and two of them appear to be covered when the side plates of the ambulacra are in place. This interesting type is so essentially distinct from all the other species of *Phænoschisma* which are known to us, that we need not make any comparisons between them.

The probability of its being an undescribed species was pointed out by one of us some years ago; and it now affords us much pleasure to name it after Mr. Bennie, to whom British Palæontology is indebted for several curious and interesting discoveries.

Localities and Horizon. East Salton and Kidlaw Quarries, near Gifford, Haddingtonshire: Shale above the No. 2 Limestone, Lower Carboniferous Limestone Group. (Presented by Dr. P. H. Carpenter, F.R.S.)

We have mentioned above that this is the only regular Blastoid which has yet been found in the Carboniferous Limestone Series of Scotland. But the same shales which have yielded both this type and *Astrocrinus Benniei* have been found by Mr. Bennie to contain fragments of ambulacra, which we cannot recognize as belonging to either species, and are not improbably those of *Mesoblastus*, *Schizoblastus*, or one of the *Granatoblastidæ.* They have been already described by one of us [1], and the figures then given are here reproduced (Pl. II. figs. 38–42).

(ii) Subfamily Cryptoschismidæ, *E. & C.*, 1886.

Definition. Ten groups of hydrospire-slits, few or none of which appear at the sides of the ambulacra. Deltoids small and external or limited to the summit.

Remarks. The two genera of which this subfamily consists are altogether unlike each other, but each of them is closely related to *Phænoschisma*, having, like that genus, the usual ten groups of hydrospires. The distinguishing character of *Cryptoschisma* is the entire concealment of the hydrospire-slits, which are in all respects like those of the Phænoschismidæ, by the wide and petaloid ambulacra (Pl. V. figs. 23, 24; Pl. XIII. fig. 20). But this condition is nearly reached, both in *Phænoschisma caryophyllatum* and in *P. acutum* (Pl. XIV. figs. 3, 4, 11). In fact one interradius in our best specimen of the latter type is altogether in the condition of *Cryptoschisma*; and if all its side plates were preserved the summit would be extremely similar to that of the latter genus (Pl. V. fig. 23; Pl. XIV. fig. 11), though the general outline of the calyx is altogether different in the two types

[1] Proc. Nat. Hist. Soc. Glasgow, 1881, vol. iv. p. 262, Pl. V. figs. 8–12; Geol. Mag. 1878, vol. v. p. 118.

(Pl. V. figs. 25, 26; Pl. XIV. fig. 10). In each alike, however, the hydrospire-slits extend far up on the sloping sides of the radial sinus and are crossed by the radio-deltoid sutures, the deltoid plates not appearing externally except in abnormal individuals (Pl. V. fig. 24).

In *Orophocrinus*, on the other hand, the deltoids appear on the exterior of the calyx above the truncated ends of the radial limbs (Pl. XI. fig. 9; Pl. XIV. figs. 14–18; Pl. XV. figs. 1, 3, 6), and the width of the radial sinus is so much reduced that the hydrospire-slits come to be concentrated at its deepest part and are not visible unless the lancet-plates are removed, and not always then (Pl. XI. fig. 9; Pl. XV. figs. 4, 8, 10, 13). In the two Belgian species, however, the radial sinuses are relatively wider, and parts of the hydrospire-slits are visible on their sloping sides, even when the ambulacra are preserved (Pl. XIV. figs. 14–18). But there is such a close relationship between them and the two other European species (Pl. XIV. figs. 4, 10) that it would be impossible to refer them to *Phænoschisma*, apart from the fact that they have deltoid plates appearing on the exterior of the calyx, and the anus distinct from the posterior spiracles.

The mutual relations of *Cryptoschisma* and *Orophocrinus* may be expressed as follows:—

Deltoids invisible externally. Spiracles small, the posterior pair confluent with the anus. Hydrospire-slits on the sloping sides of the radial sinuses, but completely concealed by the wide ambulacra.	*Cryptoschisma*, E. & C.
Deltoids visible externally. Spiracles (when present) ten linear openings, the posterior pair separate from the anus. Hydrospire-slits generally concealed and mostly concentrated at the bottom of the radial sinuses.	*Orophocrinus*, von Seebach.

Genus CRYPTOSCHISMA, gen. nov.

Pentremitidea, d'Orb. (pars), Prod. Pal. Strat. 1849, tom. i. p. 102.

Pentremitidæa, d'Orb. (pars), Cours élément. Pal. et Géol. 1852, tom. ii. fasc. 1. p. 139, fig. 1.

Pentatrematites Truncati, Roemer (pars), Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 368.

Pentremitidea, E. and C. (pars), Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 220.

Gen. Char. Calyx elongated, with a broad, flat, and truncated summit. Radial sinuses wide and open, their sloping sides pierced by hydrospire-slits, which are completely concealed by broad and petaloid ambulacra. Spiracles single or rarely double, but in the latter case the posterior pair are confluent with the anus.

Remarks. This type is represented by a single species, one of the two for which the genus *Pentremitidea* was originally established by d'Orbigny upon a character which eventually proved to be non-existent. But when we redefined *Pentremitidea* in 1882, taking as the type *P. Paillettei*, d'Arch. & de Vern., sp., we followed d'Orbigny's classification and still regarded *Pentremites Schulzi* as belonging to that genus, though we pointed out that it represented an extreme form of modification in almost every one of the generic characters. The subsequent examination of some better preserved material than was at first available has shown us, however, that the hydrospires of *Pentremites Schulzi* are formed in a totally different manner from those of *Pentremites* and *Pentremitidea* (Pl. I. figs. 6, 7; Pl. V. figs. 3, 5); for the slits are not concentrated at the bottom of the radial sinus as in those types, but are well separated from one another on the sloping sides of the radial sinus, just like those of *Codaster* and *Phænoschisma.* The slits thus pierce the radial and deltoid plates directly, as is well shown in Pl. V. fig. 24 and Pl. XVIII. fig. 2. The latter figure may be advantageously compared with fig. 1 on the same Plate (*Codaster*) and also with figs. 3–6 (*Pentremites*). The distal termination of the hydrospires against the bodies of the spade-like radials of *Cryptoschisma* is well seen in Pl. XVI. figs. 3, 4. The slits, however, are entirely concealed by the broad ambulacra, no part of them opening directly to the exterior, as is the case in the Phænoschismidæ; and it is this character which is specially distinctive of the genus. Another peculiarity is the very considerable truncation of the summit, which is more evident than in any Blastoid except *Codaster trilobatus* (Pl. XIII. figs. 1, 3, 15). The base is much elongated and often marked by a circular constriction, as shown in Pl. V. figs. 25, 26. The former figure shows that the upper part of the calyx may be sometimes bent to one side, as in the Mesozoic Holopidæ and Eugeniacrinidæ. As far as our experience goes, however, this is by no means a common character.

Species, Distribution, and Type. Cryptoschisma is represented by but one species only, the *Pentremites Schultzii* of d'Archiac and de Verneuil, which occurs at two horizons in the Lower Devonian of Spain.

CRYPTOSCHISMA SCHULZI, *d'Archiac & de Verneuil*, sp.
(Pl. V. figs. 23–26; Pl. XIII. fig. 20; Pl. XVI. figs. 3, 4; Pl. XVIII. fig. 2.)

Pentremites Schultzii, d'Arch. & de Vern., Bull. Soc. Géol. France, 1845, tom. ii. p. 479, t. 15. f. 12 *a* & *b*, f. 13 *a* & *b*.
Pentremitidea Schultii, d'Orbigny, Prod. Pal. Strat. 1849, tom. i. p. 102.
Pentremitidæa Schultii, d'Orbigny, Cours élément. Pal. et Géol. 1852, tom. ii. fasc. 1. p. 139, f. 287.
Pentatrematites Schultzii, Roemer, Archiv f. Naturgesch. Jahrg. xvii. Bd. i. p. 369, t. 7. f. 18 *a* & *b*.
Pentremites Schultzii, Dujardin & Hupé, Hist. Nat. Zooph. Échinod. 1862, p. 98.

Pentremites Schulzii, Mallada, Bol. Com. Mapa Geol. España, 1875, tomo ii. p. 79, lám. 12. f. 7, 8.

Pentremitidea Schultzii, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 223.

Sp. Char. Calyx claviform, forming in its upper part a rapidly expanding short cup; base slender, elongate, and stem-like; summit greatly expanded and abruptly truncated, the wide and flattened ambulacra giving to it a rosette-like appearance. Basal plates very much lengthened, and divided into two portions by a transverse fold-like constriction; the upper part of the united basals forms a cup of variable height, whilst the lower end is stem-like. The interbasal sutures sometimes curve considerably towards the bottom, so that the section is equally tripartite. Radial plates short, broad, and almost quadrangular; bodies but little convex; sinuses very shallow and short, the proximal ends of the radials being hardly excavated to form them. Visible parts of the deltoid plates exceedingly small, long, and cristiform. Ambulacra strongly petaloid or even deltoid, short and wide, flattened or a little concave; lancet-plate elongately petaloid; side plates fourteen on each side, narrow and oblong; outer side plates very small, placed at the extremities of the side plates, and nearly on the same level with them. Spiracles pyriform; anal spiracle rather larger than the others. Hydrospire-tubes five to eight on each side, the two inner ones the longest. Mouth large. Ornament of very fine concentric striæ. Column of strong thick joints; canal very small.

Remarks. The combination of the broad and flattened summit of this species with its elongated base gives it a very characteristic appearance in side view, especially when the calyx is bent over above the constriction in the basal cup (Pl. V. figs. 25, 26). The peculiarities of this structure have been already alluded to [1], and need not be further discussed.

The deltoid plates are normally limited to the summit, where they are so largely covered by the petaloid ambulacra that only their extreme outer ends are visible (Pl. V. fig. 23). Sometimes, however, one of them just appears on the side of the calyx (Pl. V. fig. 24); and it may also happen that the ambulacra do not reach so high on to the oral ridges as usual, thus causing the spiracles to be double instead of single, and exposing the entire length of the deltoid plates (Pl. XIII. fig. 20).

The number of hydrospire-folds appears to be somewhat variable. The section represented in Pl. XVIII. fig. 2, shows eight on each side; but only six are visible in Pl. V. fig. 24 and Pl. XVI. fig. 3, while there are only five in fig. 4 on the latter plate. This, however, represents their terminations in the body of the radial, which only receives but a very small portion of the uppermost fold on each side of the sinus.

Cryptoschisma Schulzi is such a well-defined specific type that it cannot be mistaken for any other Blastoid with which we are acquainted. The name of this species has been spelt in several ways, we ourselves having been in error when referring to

[1] *Antea*, pp. 15, 16, 20.

it. It was named by d'Archiac and de Verneuil in honour of M. D. G. Schulz, Inspector-General of Mines in Spain, and the author of a very elaborate work, 'Descripcione geológica de Asturias'[1]. We follow Don Lúcas Mallada[2] in our method of writing the name of this fossil, rather than any other authors who have dealt with it, though we prefer to write *Schulzi* and not *Schulzii*. M. Schulz has given a good account of the beds from which the Spanish *Pentremitideæ* come, especially the Ferroñes Limestone[3].

Localities and Horizon. Sabero, Province of Leon, Spain: Calcaire d'Arnao, Lower Devonian. [It is also recorded from the Calcaire de Ferroñes of the Asturias by d'Archiac and de Verneuil, and by Barrois[4].]

Genus OROPHOCRINUS, *von Seebach*, 1864.

Mitra (pars), Cumberland (non Lamk.), Reliquiæ Conservatæ, 1826, p. 31.
Pentatrematites Truncati (pars), Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 368.
Dimorphicrinus, d'Orbigny, Prodr. Pal. Strat. 1849, i. p. 155.
Dimorphicrinus, d'Orbigny, Cours élément. Pal. et Géol. Strat. 1852, tom. ii. fasc. 1. p. 140.
Orophocrinus, von Seebach, Nachr. k. Gesellsch. Wissensch. Göttingen, 1864, p. 110.
Codonites, Meek and Worthen, Proc. Acad. Nat. Sci. Philad. 1869, p. 84 (note).
Codonites, Meek and Worthen, Report Geol. Survey Illinois, 1873, vol. v. p. 463.
Orophocrinus, Zittel, Handb. Pal. 1879, Bd. i. Lief. 3. p. 434.
Orophocrinus, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 249, 1883, vol. xi. p. 226.

Gen. Char. Calyx balloon- or parachute-shaped, or truncate ob-pyramidal, longer than wide; attenuate and elongated below, expanding upwards from the base to the radial lips, which always form the periphery; section distinctly pentagonal as a rule; summit more or less convex. Basal plates forming a low but well-defined cup. Radial plates usually oblong in form, with projecting lips; sinuses narrow, sometimes slightly petaloid or nearly parallel-sided. Deltoid plates more or less spearhead-shaped, and constricted in the middle, generally visible in side view, the anal deltoid wider than the others and usually deeply excavated. Ambulacra narrow, linear to subpetaloid. Side plates large, their apposed edges excavated for the pinnule-sockets. Spiracles ten, varying from wide clefts extending along the sides of the ambulacra to narrow slits at their proximal ends; the posterior pair separate from the anus. Hydrospire-slits mostly concentrated at the bottom of the radial sinuses. Column of low and rounded or slightly pentagonal joints.

History. The name *Orophocrinus* was proposed in 1864 by von Seebach for the peculiar species *Pentremites stelliformis*, Owen and Shumard. In justice to American authors it must, however, be stated that Dr. B. F. Shumard, when referring the same species to the genus *Codaster*, remarked[5]:—"This fossil in some of its characters

[1] 8vo and 4to, Madrid, 1858.
[2] Bol. Com. Mapa Geol. España, 1875, tomo ii. p. 79.
[3] *Loc. cit.* p. 43.
[4] Mém. Soc. Géol. du Nord, 1882, tom. ii. Mém. i. p. 225.
[5] Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 385, note.

agrees with *Codaster*, but in other respects differs from that genus, and from other genera of Blastoidea. It may be necessary to create a section or subsection under another name to receive it." This suggestion was in fact carried out in 1869 by Messrs. Meek and Worthen [1], who proposed the name *Codonites* for the same species, on the ground of its differing from *Pentremites* in "having the so-called ovarian pores represented by ten distinct slit-like openings" (Pl. XI. fig. 9; Pl. XV. fig. 11). They further confirmed some previous observations of Dr. C. A. White's, made in 1863, on the presence of tegminal plates covering the mouth and ambulacral grooves [2]. A more detailed description of *Codonites* by Messrs. Meek and Worthen appeared in 1873, wherein they pointed out how their genus agreed with, and differed from, *Pentremites* and *Codaster* [3]. The views enunciated by Dr. White and by Messrs. Meek and Worthen were criticized and generally supported by the late Mr. Billings, who was led, from the structure of the hydrospire-clefts and the absence of "ambulacral pores," to consider *Codonites* as a Cystid rather than as a Blastoid [4]. The identity of *Codonites* with *Orophocrinus*, which had been universally overlooked, was first noticed by Ludwig [5] in 1878; and von Seebach's genus has been since acknowledged by Zittel [6], by ourselves [7], and by Wachsmuth [8]. It is true that the definition of *Codonites* as given by Meek and Worthen is much more complete than that of *Orophocrinus* by von Seebach; but nevertheless the latter is sufficiently full to claim priority for its author. The fact, however, that four writers had selected the same type as worthy of generic distinction, shows how very important are the characters of *Pentremites stelliformis* from a morphological point of view.

Remarks. *Orophocrinus*, like all the Codasteridæ, differs from the other genera of regular Blastoids in the absence of hydrospire-pores, so that there is but one series of openings leading to the hydrospires, viz. the ten more or less elongated clefts at the sides of the ambulacra. They are really only the unclosed portions of the radial sinuses, and correspond to the open hydrospire-canals of a *Pentremites* after the removal of the side plates which naturally roof them in (Pl. XII. fig. 13; Pl. XV. figs. 8, 10). As in *Pentremites*, there is an under lancet-plate, at any rate in the three typical species of *Orophocrinus* (Pl. XV. figs. 4, 10, 13). It only occupies the middle of the sinus in *O. pentangularis*, so that a wide cleft remains at its sides through which the hydrospires are visible. But the presence of the other ambulacral structures which rest on the under lancet-plate reduces this cleft considerably, as seen in Pl. XV. fig. 8. It is further reduced in *O. verus* (Pl. XV. fig. 4) and still more so in *O. stelliformis* (Pl. XV. fig. 13), in which type the only communication

[1] Proc. Acad. Nat. Sci. Philad. 1869, p. 84, note.

[2] Boston Journ. Nat. Hist. 1863, vol. vii. no. 4, p. 486.

[3] Report Geol. Survey Illinois, 1873, vol. v. p. 463.

[4] American Journ. Sci. 1870, vol. l. p. 234.

[5] Zeitschr. f. wiss. Zool. 1878, Bd. xxxi. p. 388.

[6] Handb. Pal. 1879, Bd. i. Lief. 3, p. 434.

[7] Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 249.

[8] Report Geol. Survey Illinois, 1883, vol. vii. p. 347.

of the hydrospires with the exterior is through the ten linear spiracles (Pl. XI. fig. 9; Pl. XV. fig. 11). On the other hand, two of the Belgian species of *Orophocrinus* (*O. Orbignyanus* and *O. Puzos*) have relatively wide radial sinuses, which are incompletely filled by the ambulacra, and portions of the uppermost hydrospire-slits are often visible at their sides, just as in *Phænoschisma*, from which this genus differs in the appearance of the deltoid plates externally (Pl. XIV. figs. 14–18). This character, together with the presence of hydrospires in the anal interradius, also separates *Orophocrinus* from *Codaster*, with which it was compared some years ago by Messrs. Meek and Worthen in the following terms [1]:—"Compared with *Codaster*, our genus [2] is found to differ in having only two of the slits mentioned in each interradial area, instead of from eight to sixteen, and in having these openings equally developed in the anal as well as in the interradial areas. The internal calcareous compressed tubes are also placed under the so-called pseudambulacral areas as in *Pentremites*, instead of occupying the whole interradial areas as in *Codaster*. It therefore seems to be an intermediate type between *Codaster* and *Pentremites*, but more nearly allied to the latter than to the former." The above passage shows that the American authors regarded the linear spiracles of *Orophocrinus stelliformis* (Pl. XV. fig. 11) as representing not merely the so-called "ovarian pores" of *Pentremites*, as they had correctly pointed out already, but also the individual hydrospire-slits of *Codaster*, of which there may be eight on each side of an ambulacrum. As a matter of fact, however, the linear spiracles of *Orophocrinus* are not single hydrospire-slits, but the remains of a radial sinus which is elsewhere closed, and corresponds to the whole space between two of the oral crests of *Codaster* (Pl. XII. figs. 1–6). The numerous transitional forms between the two genera have been fully described on pp. 88–91, and it is therefore not necessary to discuss the subject again.

Orophocrinus stelliformis was one of the types employed by the late Mr. Billings [3] (under the name of *Codonites*) in his attempt to demonstrate the fundamental identity of the hydrospire-apparatus of Cystids and Blastoids with the water-vascular system of recent Echinoderms. "The ambulacral canals of the true Crinoids and of the Starfishes are represented in a rudimentary condition in this species by the hydrospires, which open out to the surface through the ten fissure-like spiracles." He made an ingenious attempt to compare the type with *Actinocrinus* and with the Bipinnaria-larva of a starfish, regarding it as an instance of "the Occurrence of Embryonic Forms among the Palæozoic Echinoderms." But as his views rested chiefly upon the supposed fact that the mouth is merely an "ambulacral opening," and that the anus is really oro-anal in function, they need not be further discussed.

[1] Report Geol. Survey Illinois, 1873, vol. v. p. 463.

[2] *i. e. Codonites*, M. & W., = *Orophocrinus*, von Seebach.

[3] American Journ. Sci. 1870, vol. l. p. 234; Ann. & Mag. Nat. Hist. 1871, vol. vii. p. 151.

Billings regarded *Codaster* as a Cystid and not as a Blastoid because of the absence of ambulacral pores, and he naturally, therefore, took a similar view with respect to *Orophocrinus.* Meek and Worthen, however, seem to have regarded it as belonging to the Blastoidea; and it was definitely placed in this Class by Zittel, with whom we entirely agree as to this point, but we do not think that it is so closely allied to *Pentremites* as was supposed by Meek and Worthen. An approach to the form of the true Pentremite is, however, exhibited by one species in particular, the *O. gracilis*, M. & W.[1], sp., more than by any of the others. Although possessing the characteristic features of *Orophocrinus*, the upper portion of the calyx is much higher and less depressed than in the typical *O. stelliformis.*

The genus *Mitra*, Cumberland[2], is undoubtedly in part congeneric with *Orophocrinus*, and had the name not been preoccupied by Lamarck as a genus of Mollusca, it would have been necessary for us to adopt it. D'Orbigny's *Dimorphicrinus* is likewise identical with von Seebach's type. In the original definition[3] it is said to have only two rows of plates, but de Koninck and Le Hon have since stated that *Platycrinus pentangularis*, Miller, on which it was founded, is a true *Pentremites*; and we have no doubt that one of the two specimens figured by Miller[4] under this name is an imperfect example of an *Orophocrinus.*

The deltoid plates, except in well-weathered specimens, are difficult to see, but are usually acutely arrowhead-shaped in *O. pentangularis* (Pl. XV. figs. 6, 10), *O. gracilis*, and *O. Orbignyanus*, or double diamond-shaped, and constricted in the middle, as in *O. stelliformis* (Pl. XI. figs. 8, 9). The anal aperture is large, and either oval, as in the last-named species (Pl. XV. fig. 11), or elongately and roundly triangular. In *O. stelliformis* and *O. verus* (Pl. XVI. fig. 10) it also has an outer raised margin, but we have not observed any tube or small proboscis as described by Messrs. Wachsmuth and Springer[5].

The ambulacra are narrow in all but *O. stelliformis* and *O. Orbignyanus*, where they broaden out (Pl. XIV. figs. 16–18; Pl. XV. fig. 11). We have not succeeded in detecting any sign of outer side plates, unless it be in *O. Orbignyanus*, but of this we cannot be sure (Pl. XI. fig. 10). Meek and Worthen say they are unknown in *O. stelliformis* (Pl. XV. fig. 14), but they appear to figure them in *O. gracilis* (Pl. XVIII. fig. 9). The side plates are relatively very large, however, and their apposed edges are notched so as to form sockets for the reception of the ambulacral appendages, just as in *Codaster* (Pl. XIII. figs. 14, 16; Pl. XV. figs. 7, 14).

The upper parts of the lancet-plates are exposed in all the species, but towards their distal extremities the side plates often meet in the middle line and close over them, the amount of covered surface varying according to species. The side plates are

[1] Report Geol. Survey Illinois, 1873, vol. v. t. 8. f. 6.
[2] Reliquiæ Conservatæ, 1826, p. 31.
[3] Prod. Pal. Strat. 1849, i. p. 155.
[4] *Op. cit.* p. 81, fig. 2.
[5] 'Revision of the Palæocrinoidea,' Part II. 1881, p. 18, note.

very numerous in *O. verus*. *O. stelliformis* is said to possess fifty, and there are twenty-two in *O. gracilis*. There are at least twenty-five in *O. pentangularis*, and something under twenty in *O. Orbignyanus* (Pl. XI. fig. 10).

The length of the hydrospire-clefts or spiracles is a variable character. They are shortest in *O. stelliformis* (Pl. XI. fig. 8, 9; Pl. XV. fig. 11), but extend along nearly the whole length of the ambulacra in *O. pentangularis* and *O. verus* (Pl. XV. figs. 2, 8), and entirely so in *O. Orbignyanus* (Pl. XIV. figs. 16–18). The hydrospires, so far as we are acquainted with them, vary from four to twelve in number. There are five in *O. stelliformis*, from seven to twelve in *O. verus* and *O. pentangularis* (Pl. XVII. figs. 12–14), six in *O. Orbignyanus* (Pl. XI. fig. 10), and at least four in the other Belgian species, *O. Puzos*.

Species. The following are the species which we refer to *Orophocrinus*:—

Codonites campanulatus, Hambach. Burlington Group, Subcarboniferous; Iowa.
Codonites gracilis, M. & W. Burlington Group, Subcarboniferous; Iowa.
Pentremites Orbignyanus, de Koninck. Carboniferous Limestone; Belgium.
Platycrinus pentangularis, Miller (pars). Carboniferous Limestone; Lancashire, Ireland, and Belgium.
Orophocrinus prælongus, Baily. Carboniferous Limestone; County Dublin.
Pentremites Puzos, Münster. Carboniferous Limestone; Belgium.
Pentremites stelliformis, O. & S. Burlington Group, Subcarboniferous; Missouri, Iowa, Illinois.
Mitra vera, Cumberland. Carboniferous Limestone; Lancashire.

Distribution. From the above list it will be seen that *Orophocrinus* is entirely confined to rocks of the Carboniferous period, occurring, however, in those of England, Ireland, Belgium, and America. It thus has a wider geographical distribution than any of the other genera found in Britain, with the single exception of *Phænoschisma*.

Type. *Pentremites stelliformis*, Owen and Shumard.

OROPHOCRINUS STELLIFORMIS, *Owen and Shumard*, sp.[1]

(Pl. XI. figs. 8, 9; Pl. XV. figs. 11–15; Pl. XVI. figs. 5–7; Pl. XVII. fig. 12.)

Pentremites stelliformis, O. & S., Journ. Acad. Nat. Sci. Philad. 1850, vol. ii. pt. 1, p. 67, t. 7. f. 16 *a* & *b*.

Pentremites stelliformis, O. & S., Wisconsin, Iowa, and Minnesota Geol. Report, 1852, p. 593, t. v. A, f. 16 *a* & *b*.

Pentremites stelliformis, White, Boston Journ. Nat. Hist. 1863, vol. iii. no. 4, p. 486.

[1] Dr. C. A. White appears to consider his *Pentremites Sirius* (Proc. Boston Soc. Nat. Hist. 1862, vol. ix. no. 2, p. 20, f. 3) as congeneric with *O. stelliformis* (Boston Journ. Nat. Hist. 1863, vol. vii. no. 4, p. 486), and Mr. Wachsmuth has given us a hint to the same effect; but White's description and figure alone do not convey this idea to our minds at all.

Orophocrinus stelliformis, von Seebach, Nachr. K. Gesellsch. Wissensch. Gottingen, 1864, p. 110.

Codaster stelliformis, Shumard, Trans. St. Louis Acad. Sci. 1865, vol. ii. no. 2, p. 359.

Codonites stelliformis, Meek and Worthen, Proc. Acad. Nat. Sci. Philad. 1869, p. 84 (note).

Codonites stelliformis, Billings, American Journ. Sci. 1870, vol. l. p. 232. f. 10, 11.

Codonites stelliformis, Meek and Worthen, Report Geol. Survey Illinois, 1873, vol. v. p. 464, t. 9. f. 5.

Orophocrinus stelliformis, Ludwig, Zeitschr. f. wiss. Zool. 1878, Bd. xxxi. p. 389, t. 27. f. 30, 31.

Orophocrinus stelliformis, Zittel, Handb. Pal. 1879, Bd. 1. Lief. 3, p. 435, f. 309 *a* & *b*.

Orophocrinus stelliformis, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 249.

Sp. Char. Calyx pentagonal, balloon-shaped; summit depressed, convex; section deeply pentagonal; periphery almost equatorial; base narrow, expanding gradually to the basiradial sutures, and thence rapidly to the radial lips. Basal plates forming a cup which is sometimes considerably wider than high, and more or less constricted about its middle; interbasal sutures very short. Radial plates oblong, sides subparallel; bodies concave in the middle line; lips much produced; interradial sutures in depressions; sinuses long and rather petaloid, tapering more or less at their distal ends. Deltoid plates spearhead-shaped, constricted at about one third of their length from the proximal end; anal deltoid with its distal margin rounded. Ambulacra long and subpetaloid, narrowing rather suddenly at about two thirds their length from the peristome, raised above the margins of the sinuses; lancet-plates thick, broadly lanceolate, obtusely keel-shaped in section, and nearly filling the sinuses, scarcely exposed, except in the median food-groove; under lancet-plates spatulate; covering-plates often in a double series, and transversely elongated; side plates reaching fifty[1] on each side of an ambulacrum, triangular in section and much bent down laterally, but almost meeting in the middle line. Spiracles more or less curved, varying in length from one third to one half that of the ambulacra, largest at their proximal ends. Five hydrospire-folds on each side of the ambulacrum. Mouth very small, the summit plates minute and polygonal. Anus oval, bounded distally by a projecting rim or margin. Top stem-joints often anchylosed together, and filling the columnar cavity; column unknown. Ornament generally obliterated, and the surface smooth.

Remarks. We have been guided in our description of *O. stelliformis*, irrespective of the many specimens before us, by the excellent diagnosis given by Messrs. Meek and Worthen[2], but there are one or two points on which we differ from these eminent Palæontologists. We have never seen "supplemental basals," but we have observed in a longitudinal section of a calyx the anchylosed upper stem-joints filling

[1] *Fide* Meek and Worthen. [2] Report Geol. Survey Illinois, 1873, vol. v. p. 464.

up the columnar cavity at the base. Neither do we agree with them as to the disposition of the hydrospire-clefts in relation to the ambulacra, a point to which we have already alluded on pp. 98, 99[1]. We can give a general confirmation to Dr. White's description of the summit plates[2]; and we agree both with him and with Messrs. Meek and Worthen[3] that these pieces did not possess the mobility necessary to their being opened and closed at will. On the other hand, we have not been fortunate enough to observe anal covering plates, except perhaps in one of Mr. Wachsmuth's specimens; nor have we seen any definite traces of an anal tube or proboscis in *Orophocrinus*, and presumably in this species, as described by Messrs. Wachsmuth and Springer[4]. If the anal plates are arranged in the form of a small tube or proboscis, we can quite reconcile their statement with Dr. White's description by supposing that in his specimens the plates were accidentally pressed within the opening.

A remarkable feature in *O. stelliformis* is the distance between the proximal side plates and the radial centre (Pl. XV. fig. 11). It is more apparent in this than in any other species of *Orophocrinus*, but there are a series of gradations between it and *O. pentangularis*, in which the intervening space is least (Pl. XV. fig. 8).

We have indicated the points which distinguish this species from *Orophocrinus verus*, Cumb., sp., in the description of the latter type. *O. gracilis*, M. & W.[5], is at once separated by the more strictly Pentremite-like outline of its calyx.

Localities and Horizon. Burlington, Iowa; Lower Burlington Limestone, Subcarboniferous. [Shumard[6] also gives Hannibal, Missouri; and Monmouth, Illinois.]

OROPHOCRINUS STELLIFORMIS, var. CAMPANULATUS, *Hambach*, var.

(Pl. XVI. fig. 5.)

Codonites campanulatus, Hambach, Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 4, p. 553, t. D. f. 8, 9.

Remarks. Two small specimens in the Collection differ from the typical *O. stelliformis* in possessing a bell-shaped body, shorter ambulacra, longer and less concave sides between the basiradial suture and the radial lips, which are less prominent than in the type (Pl. XVI. fig. 7). These individuals appear to us to correspond with Mr. Hambach's *Codonites campanulatus*, which we take to be only a variety of *O. stelliformis*, and not a distinct species. We do not think that there is a much

[1] Ann. & Mag. Nat. Hist. 1883, vol. xi. p. 236.
[2] Boston Journ. Nat. Hist. vol. vii. no. 4, p. 486.
[3] Proc. Acad. Nat. Sci. Philad. 1869, p. 85.
[4] Revision of the Palæocrinoidea, Part II. 1881, p. 18, note.
[5] Report Geol. Survey Illinois, vol. v. t. 8. f. 6.
[6] Trans. St. Louis Acad. Sci. 1858, vol. i. no. 2, p. 247.

greater difference between it and the typical form than between our different examples of *O. verus* (Pl. XV. figs. 1, 3) or of *O. pentangularis* (Pl. XV. figs. 6, 9).

Locality and Horizon. Burlington, Iowa ; Lower Burlington Limestone, Subcarboniferous. [Hambach's locality is Sedalia, Missouri.]

OROPHOCRINUS VERUS, *Cumberland*, sp.

(Pl. XII. fig. 9 ; Pl. XIII. fig. 16 ; Pl. XV. figs. 1–4 ; Pl. XVI. fig. 10 ; Pl. XVII. fig. 13.)

Mitra vera, Cumberland, Reliquiæ Conservatæ, 1826, p. 31, t. B. f. 1, 2.
Pentatrematites inflata, G. B. Sby., Zool. Journ. 1829, vol. iv. p. 90, *ibid.* 1835, vol. v. t. 33, Suppl. f. 2.
Pentremites inflatus, Phillips, Ill. Geol. York. pt. 2, 1836, p. 207, t. 3. f. 1–3.
Pentatrematites inflatus, Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 357 (excl. syn. de Koninck).
Pentremites inflatus, Dujardin & Hupé, Hist. Nat. Zooph. Echinod. 1862, p. 92.
Pentremites inflatus, Rofe, Geol. Mag. 1865, vol. ii. p. 250, t. 8. f. 9.
Orophocrinus inflatus, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 252.

Sp. Char. Calyx depressed pyriform, or balloon-shaped, expanding gradually upwards from the base; summit depressed convex; section distinctly pentagonal, with shallow reentering angles; periphery either equatorial or nearer the base than the summit. Basal plates long, large, convex, higher than wide. Radial plates large, prominent, arched, occupying almost two thirds the entire height of the calyx, longer than wide, narrowed below, with their surfaces in two unequal planes, the upper one formed by the limbs being much the longer; interradial sutures in wide depressions : sinuses long and narrow, longitudinally arched, with simple margins. Deltoid plates rhombic, small, as compared with the radials; the anal deltoid obtusely rounded distally. Ambulacra long, narrow, and raised above the margins of the sinuses; ambulacral grooves broad at their proximal ends, exposing the lancet-plates, but rapidly attenuating outwards; lancet-plates large, shallow and boat-shaped, occupying almost the whole width of the sinuses, deeply excavated for the reception of the large side plates, which almost conceal them. Hydrospire-folds seven to twelve ; tubes long and curved; sacs pyriform. Spiracles narrow, extending externally along quite three fifths the length of the ambulacra, but shorter internally. Anus oval, its distal margin projecting and lip-like, the proximal margin overhanging the aperture, after the manner of a hood. Ornament very fine and minute, usually not preserved.

Remarks. We are convinced that *Mitra vera*, Cumberland, and the subsequently described *Pentatrematites inflata*, G. B. Sby., are identical. A perfectly clear, although brief description, as well as a good figure, was given by Cumberland, and in

justice to one of the earliest workers in British Palæontology we adopt his name for the species in question, which forms the British type of the genus *Orophocrinus.*

Prof. F. Roemer [1] was the first to suggest the necessity of separating *P. inflata,* Sby., from the typical Pentremites on account of the absence of outer side plates in the ambulacra; and the want of hydrospire-pores was subsequently pointed out by Rofe [2], who took the linear spiracular clefts to be mere grooves in which the pinnules were inserted, and stated in consequence that this species, together with "*P. Waterhousei* (de Koninck) differ from all the above (*i. e.* American *Pentremites*) as they do not show the summit-openings from which this genus derives its name; but they have one large circular opening at the summit of one of the quadrilateral plates, in the place usually occupied by the largest of these openings, and which is shown by Prof. Forbes to be anal."

The resemblance of the external form of this species to that of *Orophocrinus stelliformis* was noticed by Meek & Worthen [3] when they made the latter the type of their new genus *Codonites,* but in the absence of good figures of *O. verus,* they were unable to carry their comparison any further. The resemblance in general character between *O. verus* and *O. stelliformis* is a very marked one; but the proportions of the component parts of the calyx are different, so that the former has a less lobate outline, narrower sinuses, a more convex summit, and longer spiracles (Pl. XV. figs. 1–4, 11, 13). The side plates in *O. verus* are numerous, but less so than in *O. stelliformis,* which is said to possess fifty on each side of an ambulacrum, whilst the former has only from forty to forty-five. On the other hand, both species are alike in their anal apertures having thickened and prominent distal margins (Pl. XV. figs. 3, 11; Pl. XVI. fig. 10). In *O. pentangularis,* Miller, sp., the calyx is much longer, the ambulacra shorter and less convex, and the summit more constricted (Pl. XV. figs. 5, 6, 8, 9). We give a very instructive figure of an ambulacral field of *O. verus,* with the side plates and lancet-plate entirely removed, so as to show the under lancet-plate (Pl. XV. fig. 4). The hydrospire-clefts, which are visible externally along the sides of the ambulacra, only communicate internally with the hydrospires by their pyriform proximal ends. In the allied species, *O. pentangularis,* the extension and enlargement of these openings as compared with those of *O. verus* is very noticeable (Pl. XV. fig. 10), while they are smaller in the American *O. stelliformis* (Pl. XV. fig. 13).

We figure two well-marked varieties of *O. verus,* in which the difference in the relative heights of the calyces, between the base and the radial lips, is well shown. In the first (Pl. XV. fig. 3) the ambulacra are relatively long whilst those parts of the calyx which lie below the lips are proportionately reduced. In the other specimen

[1] Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 357.

[2] Geol. Mag. 1865, vol. ii. p. 250.

[3] Report Geol. Survey Illinois, 1873, vol. v. p. 466.

(Pl. XV. fig. 1) the calyx generally is more elongated, and the ambulacra shortened, thus indicating a departure towards the other British species *O. pentangularis*, Miller, sp. (Pl. XV. figs. 6, 9). The specimens agree so closely in other respects that it would be impossible to separate them specifically; and we are the less inclined to do so because our study of the Blastoidea has shown, in the plainest possible manner, that there is a large amount of variability in the characters of a species.

Localities and Horizon. Whitewell, in Bolland, Lancashire (Presented by the late Mr. John Rofe, F.G.S.); Preston, Lancashire: Carboniferous Limestone.

Orophocrinus pentangularis, *Miller*, sp.
(Pl. XV. figs. 5–9; Pl. XVI. figs. 8, 9; Pl. XVII. fig. 14.)

Platycrinites pentangularis, Miller (pars), Nat. Hist. Crinoidea, 1821, p. 83 [t. 29. figs. 2, 6, 7].
Mitra depressa, Cumberland, Reliquiæ Conservatæ, 1826, p. 33, t. B. f. 3.
Pentatrematites pentangularis, G. B. Sby., Zool. Journ. 1855, vol. v. p. 467, t. 33, Suppl. f. 7.
Pentremites pentangularis, Phillips, Ill. Geol. Yorks. pt. 2, 1836, p. 207.
Dimorphicrinus pentangularis, d'Orbigny, Prod. de Pal. Strat. 1849, tom. i. p. 155.
Pentatrematites pentangularis, Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 371.
Pentremites pentagonalis, Morris, Cat. Brit. Foss. 2nd edit. 1854, p. 86.
Pentremites Waterhousianus, de Koninck & le Hon, Mém. Acad. Roy. Belgique, 1854, tom. xxviii. Mém. 3, p. 203, t. 7. f. 6 *a–c*.
Pentremites pentangularis, Dujardin & Hupé, Hist. Nat. Zooph. Échinod. 1862, p. 98.
Pentremites Waterhousei, Rofe, Geol. Mag. 1865, vol. ii. p. 250.
Orophocrinus pentangularis, et O. *Waterhousianus*, E. & C., Ann. & Mag. Nat. Hist. 1882, vol. ix. p. 252.
Orophocrinus (*Pentremites*) *prælongus*, Baily (pars), Proc. Roy. Dub. Soc. 1886, vol. v. pt. 1, p. 31, t. i. f. 2, 2 *a*, 2 *b*.

Sp. Char. Calyx a truncated pentagonal pyramid, or elongately parachute-shaped, narrow and funnel-like below, expanding very gradually upwards; summit gently convex, or somewhat depressed in the centre; periphery at less than a third from the summit, the disproportion in height between the parts above and below this level being very apparent. Basal plates elongate, higher than wide, forming a funnel-shaped cup. Radial plates oblong, large, increasing but little in width, forming quite, if not more than, two thirds the entire length of the calyx; bodies obtusely rounded and prominent in the middle line, much longer than the limbs; interradial sutures placed in depressions; sinuses narrow and short, with simple margins; lips prominent. Deltoid plates small and rhombic, the anal deltoid rather larger than its fellows, and rounded along its distal margin. Ambulacra short and narrow, raised but little above the margins of the sinuses; side plates about twenty-five; lancet-plate partially covered at its proximal end, and entirely so distally, boat-shaped in section; hydrospire-clefts extending almost the whole length of the ambulacra, but

only just reaching the deltoid plates at their proximal ends. Hydrospire-folds six to eight in number ; the tubes short and curving inwards. Mouth small. Anus at the proximal end of the posterior deltoid. Column circular; canal large. Ornament seldom preserved, but when so the striæ are fine and regular, and usually well marked on the outwardly bevelled margins of the radial sinuses.

Remarks. Orophocrinus pentangularis was originally described by Miller as a *Platycrinus*, but, according to Mr. G. B. Sowerby, arms were added to one of his figures to increase the resemblance to this generic type ! [1] Notwithstanding this, Miller's other figure and description are a clear interpretation of the species meant, and therefore Cumberland's more accurately defined but later name cannot be adopted. *Platycrinites pentangularis*, Miller, sp., also formed the type of d'Orbigny's genus *Dimorphicrinus*, which, however, has never been adopted by palæontologists on account of the erroneous and incomplete nature of his generic diagnosis.

The radial plates of *O. pentangularis* are each marked by four impressed lines radiating from the lips to the basiradial sutures. Two of these are almost in the middle line, and bound the obtusely convex central portions of the plates, whilst the other two pass to the lateral angles. The edges of the radials are bevelled outwards along the sinuses, and the resulting surfaces are marked with cross striæ. On the two limbs forming the anal interradius the bevelled portions are wider and more pronounced, while the cross striæ are stronger.

We have carefully studied the unique specimen of *Pentremites Waterhousianus*, de Kon. and le Hon (Pl. XV. figs. 8–10; Pl. XVI. figs. 8, 9), and we regret that we cannot agree with these eminent writers in regarding it as distinct from Miller's species. The specimen, so far as the summit characters are concerned, is in a better state of preservation than the generality of British Blastoids, but the structure of the parts is identical with that of *O. pentangularis*, even including the ornament of the calyx. The base of the Belgian fossil, on the other hand, was clearly injured and partially distorted during the life of the Blastoid, as indeed its describers pointed out. The reparation of this injury seems to have been accompanied by the growth of extra plates around the base, and the partial covering of these plates with a secondary deposit of calcareous matter, so as to give a spurious ornamentation to the lower portion of the cup.

Orophocrinus pentangularis may be distinguished from *O. stelliformis*, *O. gracilis*, and *O. verus* by the increased height of the calyx between the columnar articulation and the radial lips, by its shorter ambulacra and depressed summit, and by its wide and long hydrospire-clefts. It does not appear to be a common species, judging from the small number of examples that we have met with. Good sections for the microscope are difficult to obtain, and our figure of the hydrospires

[1] Zool. Journ. 1834, vol. v. no. 20, p. 457.

(Pl. XVII. fig. 14) represents the best we have been able to procure. Seven hydrospires are visible on one side of the ambulacrum, and eight on the other.

Localities and Horizon. Bolland, Lancashire; Clitheroe, Lancashire (Presented by Mr. J. Rofe, F.G.S.); [County Dublin, as *O. prælongus*, Baily]: Carboniferous Limestone. [Miller mentions Weston-super-Mare, Somersetshire, Black Rock, Avon Section, Bristol, and Mitchell-Dean, Gloucestershire.] Tournay, Belgium (as *O. Waterhousianus*, de Kon. & le Hon sp.): Upper Carboniferous Shale.

Order IRREGULARES, *E. & C.*, 1886.

Definition. Unstalked Blastoids in which one ambulacrum and the corresponding radial are different from their fellows.

Remarks. We have established this Order to include three very remarkable genera of Blastoids, our knowledge of which is far from being as complete as we could wish. The best known of these is the *Eleutherocrinus* of Shumard and Yandell[1], two species of which occur in the Devonian Rocks of America (Pl. XIX. figs. 2–6). Some ten years after it was first described, its differences from the other Blastoids were recognized by Haeckel[2], who gave expression to them in the following manner. He divided the Class into two Orders, and in the first of these, which he called Elæacrina, he placed the three genera *Pentremites*, *Codaster*, and *Elæacrinus*, with the following remark: "Abgesehen von dem excentrischen After, ist die Grundform fast regelmässig pentactinot, nicht amphipleurisch." The second order, Eleutherocrina, included but the single genus *Eleutherocrinus*, which differs from the three types already mentioned in "die sehr starke Differenzirung ihrer Antimeren und die ausgezeichnete Pentamphipleuren Form." In a later work[3], the name of the first order is changed to Pentremitida, which are described as the "Regularly Budding Lilies," while the Eleutherocrina are "Lilies budding on two sides," a description which we cannot altogether understand.

On the other hand, we have no hesitation in saying that the diagnosis of *Eleutherocrinus* which was published by Shumard and Yandell in 1856 is by far the best account of a new generic type with which we are acquainted. The genus is a most singular one in every way, and we have found with great interest that its chief peculiarities are repeated in the curious little *Astrocrinus* of the British Carboniferous Limestone (Pl. XX.), and also, though to a less extent, in the little known *Pentephyllum* (Pl. XVI. figs. 14–16).

Eleutherocrinus, as seen from its anterior side (Pl. XIX. fig. 4), might readily be mistaken for an ordinary regular Blastoid, such as *Mesoblastus* (Pl. VI. fig. 12). But

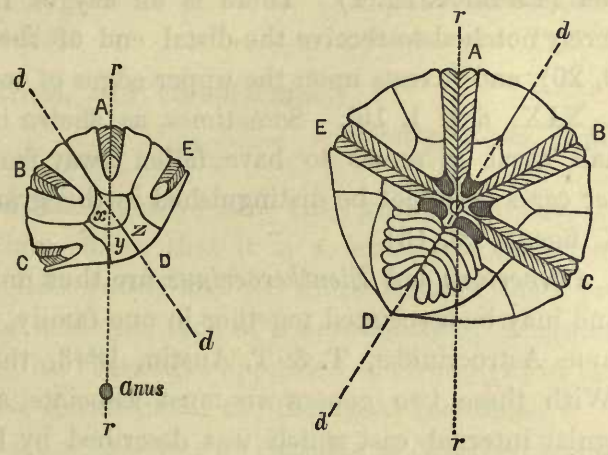
[1] Proc. Acad. Nat. Sci. Philad. 1856, vol. viii. p. 54.

[2] Generelle Morphologie der Organismen (Berlin, 1866), Bd. ii. p. lxix.

[3] History of Creation (London, 1876), vol. ii. p. 166.

a glance at its base or summit (Fig. VIII.), or at the azygos interradius, is sufficient to show that it is an altogether anomalous type (Pl. XIX. figs. 5, 6). In the first place it has no trace of a stem, but the situation of the ordinary columnar facet at the point of convergence of the ambulacra is occupied by the small azygos basal, *x*, which is thus strictly dorsocentral in its position. Hall[1], however, in describing a

Fig. VIII.



A B

Diagrams to show the relations of the dorsal and radial axes in *Eleutherocrinus Cassedayi* (adapted from Shumard and Yandell). A, dorsal, and B, ventral aspect.

A, B, C, D, E. The five radii of the calyx. *x*. The small azygos basal. *y*, *z*. The two larger basals. *d . . . d*. The dorsal axis. *r . . . r*. The radial axis, in which the anus is situated.

new species (*E. Whitfieldi*), speaks of it somewhat infelicitously as the "Ventral basal plate." Two of the radials, A and B, rest directly against the anterior edges of this azygos basal, while its rounded posterior border is in contact with two long and narrow plates, the paired basals, *y* and *z*, which extend nearly halfway up the side of the calyx (Pl. XIX. fig. 5), and support a single spade-like radial closely resembling the radial plates of some species of *Codaster* (Pl. XIII. fig. 3). The other four radials are deeply incised by narrow ambulacra of the usual character, but the two which are in contact with the azygos one are naturally slightly different from their fellows. Their ambulacra (C and E) are almost in a straight line (Fig. VIII.; Pl. XIX. fig. 6), instead of forming an angle of twice 72° as in the regular Blastoids, and the azygos ambulacrum between them is altogether different from them. It is unusually wide, and entirely limited to the summit of the calyx. This is well seen in Mr. Wachsmuth's specimen (Pl. XIX. fig. 6), which also shows the three normal deltoids, though we have not been able to make out the spiracles figured by Shumard

[1] Fifteenth Ann. Rep. New York State Cab. Nat. Hist. 1862, p. 151.

and Yandell. One of the two at the origin of the odd ambulacrum is probably the anal spiracle, as we have endeavoured to point out on pp. 14, 15.

We cannot venture to offer any explanation of these striking peculiarities of *Eleutherocrinus*, but will pass on to consider its resemblance to the Carboniferous genus *Astrocrinus*, which is closer than would appear at first sight. *Astrocrinus* has four long and narrow ambulacra, which cross one another almost at right angles, and a short odd one as well (Pl. XIX. fig. 1). There is an azygos radial which is not incised at all, but merely notched to receive the distal end of the odd ambulacrum (Pl. XX. figs. 14, 19, 20), and it rests upon the upper edges of two long basals, as in *Eleutherocrinus* (Pl. XIX. figs. 1, 15). Sometimes, as shown in the first of these two figures, the small basal, *x*, seems to have fallen away from its dorsocentral position ; but in other cases it cannot be distinguished in the granular lower surface of the calyx (Pl. XX. figs. 8, 10, 13).

These two genera, *Astrocrinus* and *Eleutherocrinus*, are thus united by several very definite characters, and may be associated together in one family, for which it is only right to use the name Astrocrinidæ, T. & T. Austin, 1843, though it was never formally defined. With these two genera we must associate, at any rate for the present, the very singular internal cast which was described by Haughton[1] in 1859 as *Pentephyllum Adarense* (Pl. XVI. figs. 14–16). It is unstalked, like *Eleutherocrinus* and *Astrocrinus*, so that the physiological condition which is presented by *Marsupites* and *Uintacrinus* among the Neocrinoids, to say nothing of the Comatulæ, was also reached by some half dozen members of the older group of Blastoids. For the opportunity of examining this fossil we are indebted to our friend Prof. W. J. Sollas, F.G.S., of Trinity College, Dublin. It is not altogether symmetrical in outline, but its base is very regularly pentagonal (Pl. XVI. fig. 16), a character which at once distinguishes it from *Astrocrinus* and *Eleutherocrinus* (Fig. VIII, A). Its deltoid plates are large like those of *Astrocrinus*, and the radio-deltoid sutures have exactly the same relations as in *Codaster* (Pl. XII. figs. 1, 4), descending the sloping sides of the radial sinuses and meeting the ambulacra nearly at right angles (Pl. XVI. figs. 14, 15). The interambulacral angles are not equal, however, as they are in the regular Blastoids, but they have the same want of symmetry as *Eleutherocrinus*, four of them taking up a little more than 180° of the summit. There is a fracture in the summit at the origin of the odd ambulacrum, but enough remains to show that this was linear like its fellows (Pl. XVI. fig. 14), and not largely modified as in *Astrocrinus* and *Eleutherocrinus* (Pl. XIX. figs. 1, 6).

Pentephyllum then clearly belongs to the Order Irregulares, and until we know more about it, we think that it had better be placed in the family Astrocrinidæ, which will have the same definition as the Order.

1 "On a new Carboniferous Echinoderm, from the County of Limerick." Journ. Geol. Soc. Dublin, 1859, vol. viii. p. 183, pl xxix.

Family *ASTROCRINIDÆ*, T. & T. Austin, 1843 (emend. E. & C., 1886).

(i.) Basals unsymmetrical. Azygos radial small and without definite limbs; its ambulacrum short, wide, and horizontal.	
Calyx ovoid	*Eleutherocrinus*, Shumard and Yandell.
Calyx low and stellate	*Astrocrinus*, T. & T. Austin.
(ii.) Basals symmetrical, odd ambulacrum linear	*Pentephyllum*, Haughton.

We have divided the family into two groups, because even the little we know of *Pentephyllum* shows that it is a much less abnormal form than either *Eleutherocrinus* or *Astrocrinus*, and we think it more than probable that it will eventually have to be made the type of a new family of irregular Blastoids. Under these circumstances, the characters appended to Group (i.) in the above scheme will become the distinctive characters of the family Astrocrinidæ.

The National Collection contains no example of *Eleutherocrinus*, and we are therefore precluded from describing it. We regret this the less, however, as an excellent diagnosis of it has been already given by Shumard and Yandell; and by the kindness of Mr. Wachsmuth we have been enabled to give some figures of the genus on Plate XIX. for comparison with those of *Astrocrinus* on the next Plate.

Genus ASTROCRINUS, *T. & T. Austin*, 1842 (*emend. E. & C.*, 1886).

Astrocrinites, T. & T. Austin (MS.)[1], Ann. & Mag. Nat. Hist. 1842, vol. x. p. 112; *Ibid.* 1843, vol. xi. p. 205.

Zygocrinus, Bronn, Index Pal. Nomen. 1848, p. 1381.

Zygocrinus, Roemer, Archiv f. Naturgesch. 1851, Jahrg. xvii. Bd. i. p. 392.

Zygocrinus, De Koninck & Le Hon, Mém. Acad. Roy. Belgique, 1854, tom. xxviii. Mém. 3, p. 189.

Astrocrinus, Morris, Cat. Brit. Foss. 2nd edit. 1854, p. 72.

Zygocrinus, Pictet, Traité de Pal. Strat. 1857, tom. iv. p. 295.

Astrocrinites, Etheridge, Jr., Quart. Journ. Geol. Soc. 1876, vol. xxxii. p. 103.

Astrocrinus, E. & C., Ann. & Mag. Nat. Hist. 1883, vol. xi. p. 234.

Gen. Char. Calyx free, obtusely tetralobate, with one of the ambulacra peculiarly modified; summit truncate and flattened; base resembling it, or sometimes a little pointed. Basal plates unsymmetrical and not united to form a cup, the azygos one being more or less triangular, and dorsocentral in position; the other two alike, and

[1] Non *Asterocrinites*, Münster, Beiträge zur Petrefactenkunde, 1843, Heft 1, p. 33; nec *Asterocrinus*, Lyon, D. D. Owen's 3rd Report Geol. Survey Kentucky, 1857, p. 472.

elongately triangular, extending upwards to support the azygos radial. Four of the radial plates are generally alike, A and B being slightly different from C and E, which have modified posterior limbs; but the relative proportions of the bodies and limbs, and the length of the latter vary greatly. The fifth radial is shorter than the others, somewhat rhombic in outline, not forked or divided into body and limbs, but simply emarginate above, resting on the sloping upper edges of the two similar basals. Deltoid plates dissimilar, three of them roughly oblong and subequal in size, the two others much smaller, and placed at the sides of the odd ambulacrum. Four of the ambulacra are lanceolate-linear, with side and outer side plates as usual, and almost reach the dorsal surface; lancet-plates partially exposed throughout the whole length of the ambulacra; the fifth or right postero-lateral ambulacrum (D) is modified, being shortened, subtriangular, and horizontal. One hydrospire-fold on each side of the radial sinus. Spiracles unknown. Mouth large. Anus unknown. Ornament consisting of tubercles and spines.

History. This interesting genus was originally proposed by the Messrs. Austin in 1842, and briefly defined a year later. Dr. Bronn, in his wonderfully accurate 'Nomenclator,' rejected the name *Astrocrinites* on account of its resemblance to *Asterocrinites*, Münster, and proposed *Zygocrinus* in its place. Our friend Prof. F. Roemer published a few remarks on this genus in 1851. On account of its apparently tetraradiate structure, he considered it to have a greater resemblance to the Cystidea than to the Blastoidea. On the other hand, Messrs. de Koninck and Le Hon referred it to the latter group. In 1854 Prof. John Morris altered Austin's name to the form by which it is now generally known, *Astrocrinus*. The late Prof. Pictet, in 1857, followed Bronn, and de Koninck and Le Hon, by using the term *Zygocrinus*, and, like the latter authors, he placed the genus among the Blastoidea. From this time forward nothing more appears to have been written on *Astrocrinus* until 1876, when one of the present writers described a second species from the Scotch Carboniferous Limestone Series, and entered into the general question of the affinities of the genus. Although some of the statements contained in this paper have required subsequent modification, more especially those relating to the odd ambulacrum, the general description of the type and the views therein set forth still hold good. Lastly, in 1883, the present writers conjointly effected the required change in the nomenclature of the various parts of *Astrocrinus*, and pointed out its affinities with *Eleutherocrinus*.

Remarks. This aberrant member of the Blastoidea is distinguished from all other genera of the class, with the exception of *Eleutherocrinus* (Pl. XIX. fig. 6), by the peculiar modification, or apparently abortive condition, of one of its ambulacra. This gives a tetraradiate appearance to the calyx, although, so far as the ambulacra are concerned, its symmetry is pentamerous, as in all Blastoids. It is further peculiar but possibly not unique in the presence of superficial tubercles which had minute

spines articulated to them (Pl. XX. figs. 5, 12). When *Astrocrinus* is compared with any of the regular Blastoids, the normal ambulacra are seen to lie in deep depressions between the projecting lobes or interradii in such a manner that the lines of union of contiguous radial limbs are placed on convexities (Pl. XX. figs. 1, 12, 13, 16). On the other hand, in the regular Blastoidea, any lobe-like extensions of the general periphery are caused by the projection of those parts of the radial plates into which the distal ends of the ambulacra are received, whereby the interradial sutures are placed in depressions, or, at all events, not on projecting portions of the calyx (Pl. IV. figs. 8, 10, 12; Pl. XV. fig. 11). The azygos ray of *Astrocrinus*, however, differs from the other four ambulacra in occupying a projection and not a depression of the calyx, so that three of its four lobes are interradial, while the fifth is radial (Pl. XIX. fig. 1; Pl. XX. figs. 1, 7–16). Although *Astrocrinus* has been considered to be a Cystid, we have little doubt that it is a Blastoid, and closely allied to the singular genus *Eleutherocrinus*, as we have already explained.

The deltoids are much larger in *Astrocrinus* than in *Eleutherocrinus*, and as in the latter type (Pl. XIX. fig. 6) those on either side of the azygos ambulacrum differ from the other three in outline (Pl. XX. figs. 2, 11, 12, 15, 16). As in some species of *Schizoblastus* (e. g. *S. Sayi*), the proximal ends of the deltoid plates immediately surrounding the mouth are sometimes much constricted, so that one of the writers was formerly misled into considering them as separate elements of the calyx. We are only partially acquainted with the hydrospires of *Astrocrinus*, but, judging from the internal appearance presented by some isolated radial plates (Pl. XX. figs. 4, 18, 20), we think it not only possible but probable that the hydrospires were situated partially or entirely within the substance of these plates, as they are in *Tricœlocrinus* (Pl. XVIII. fig. 11).

While closely related to *Eleutherocrinus* in general structure, so far as it can be made out, *Astrocrinus* presents several points of difference from that type. It is much smaller and altogether dissimilar in appearance, being flattened and more or less distinctly stellate or lobate (Pl. XX.). The outline varies considerably, the anterior lobe (*i. e.* that opposite the azygos ambulacrum) being considerably produced in some forms (Pl. XIX. fig. 1; Pl. XX. figs. 9–13), and in others comparatively short (Pl. XX. figs. 7, 8, 14). The four normal ambulacra cross one another nearly at right angles. This is very far from being the case in *Eleutherocrinus*, where they occupy a little more than 180° of the summit, as is well shown in our figure (Pl. XVIII. fig. 6), so that the odd ambulacrum takes up a relatively larger portion of the summit than in *Astrocrinus* (Pl. XVIII. fig. 1). Pictet's views[1] as to the analogy of *Astrocrinus* with *Codaster* are altogether untenable. He appears to have quite forgotten the hydrospires of *Codaster*, though they had been described and well figured by Roemer. The only possible resemblance between the two types is that the summit

[1] Traité de Paléontologie, tom. iv. p. 295.

of *Astrocrinus* is slightly truncated. But apart from the nature of the hydrospires, *Codaster* is symmetrical, and has an anal opening (Pl. XIII. figs. 1, 4), which is absent in the markedly asymmetrical *Astrocrinus*. Even with *Elæacrinus*, which departs a little from the ordinary symmetry of the regular Blastoids, *Astrocrinus* has nothing in common. In the former genus the modification is due to the intercalation of an anal plate, all the ambulacra being alike (Pl. XVIII. fig. 19); but this is very far from being the case in *Astrocrinus*.

Species. We are acquainted with but two species of *Astrocrinus*:—

Astrocrinites Benniei, Eth. Jn. Carboniferous Limestone; South of Scotland.

Astrocrinites tetragonus, T. & T. Austin. Carboniferous Limestone; Yorkshire.

Distribution. The genus is essentially a British one, and is confined to rocks of Carboniferous age.

Type. *Astrocrinites tetragonus*, T. & T. Austin.

ASTROCRINUS TETRAGONUS, *T. & T. Austin*.

(Pl. XX. figs. 1, 2.)

Astracrinites tetragonus, Ann. & Mag. Nat. Hist. 1842, vol. x. p. 110.
Astrocrinites tetragonus, T. & T. Austin, *Ibid.* 1843, vol. xi. p. 206.
Astrocrinus tetragonus, Morris, Cat. Brit. Foss. 2nd edit. 1854, p. 72.
Astrocrinites tetragonus, Etheridge, Jun., Quart. Journ. Geol. Soc. 1876, vol. xxxii. t. 13. f. 26.
Astrocrinus tetragonus, E. & C., Ann. & Mag. Nat. Hist. 1883, vol. xi. p. 237.

Remarks. We are unable to frame a satisfactory diagnosis of this type owing to the imperfect state of preservation of all the specimens which we have seen. There are only two in the National Collection, and a few others in the Museums at York and Liverpool. The Woodwardian Museum at Cambridge, the geological collection at Owens College, Manchester, and that at Giggleswick Grammar School also contain examples of the type which we have been permitted to examine; and our thanks are due to Prof. T. McK. Hughes, F.G.S., Prof. W. Boyd Dawkins, F.R.S., and to the Rev. G. Style, M.A., for thus facilitating our work. The specific definition given by the Messrs. Austin[1] contains the following passage:—"Near the centre of the dorso-central plate is an oval eminence, apparently analogous to the *madreporiform tubercle* on the dorsal surface of the true Starfishes." The dorsocentral plate of Austin is the azygos basal (x), but neither in this species nor in *A. Benniei* (Pl. XX. figs. 8, 10, 13) have we found anything like the structure described by the Messrs. Austin, and it is almost needless to observe that we should not expect to find a madreporic plate in any member of the Pelmatozoa.

It is possible that the next species to be described, *Astrocrinus Benniei*, may be identical with Austin's type, but as the characters of the former are well defined, and it is tolerably abundant in certain localities, and marks a well-known horizon, we prefer to regard the two forms as distinct from one another. So far, however, as

[1] Ann. & Mag. Nat. Hist. 1843, vol. xi. pp. 205, 206.

our material will permit us to form an opinion, *A. tetragonus* appears to be a considerably larger and more robust species than *A. Benniei*, and this variation in habit was probably accompanied by other structural differences.

Locality and Horizon. Settle, Yorkshire; Carboniferous Limestone.

ASTROCRINUS BENNIEI, *Etheridge, Jun.*

(Pl. XIX. fig. 1; Pl. XX. figs. 3–20.)

Astrocrinites Benniei, Etheridge, Jun., Quart. Journ. Geol. Soc. 1876, vol. xxxii. p. 103, t. 12. f. 1–11, t. 13. f. 12–22.

Astrocrinus Benniei, E. & C., Ann. & Mag. Nat. Hist. 1883, vol. xi. p. 237.

Sp. Char. Calyx depressed-stellate, with deep reentering angles between the lobes; anterior interradius occasionally much produced, though it may be shorter than either of the lateral ones; summit flattened or a little concave; base flattened or slightly convex. The azygos basal plate rounded triangular, the two others reaching at most to the periphery. The two anterior radial plates are entire, regular, equal, convex, narrowed below and expanding upwards, with their limbs reaching upwards to the periphery; the two postero-lateral radials agree with the anterior pair in every particular except that the posterior limb in each, which is next to the azygos lobe, is only partially developed; the fifth radial is broadly triangular or rhombic, convex, and a little pointed below. The four sinuses are short, extending for about a third the length of the radials, with prominent lips; the fifth sinus is only represented by an emargination of the upper edge of the azygos radial, and the lip is not well defined. The anterior and two lateral deltoids are relatively large and strongly cristiform, with constricted central ends. The four normal ambulacra are long, slightly petaloid, and cross one another nearly at right angles; lancet-plates narrow; side plates fifteen or more, inclined at a high angle; the fifth or modified ambulacrum more or less petaloid, with about five side plates on each side. One hydrospire-fold on each side of an ambulacrum. The entire dorsal or lower surface of the calyx is ornamented with closely-set, sharp, and tooth-like tubercles, with a plain smooth apex and fluted sides, the tubercles becoming conical and obtuse on the radial limbs. The crests of the deltoid plates have three or more rows of these tubercles, the central row being the largest; some of them at least were punctate, and probably had spines attached; the two elongated basals were marked with transverse scale-like ridges, and the azygos radial plate which rests upon them has similar ridges arranged in a vertical direction.

Remarks. Since the description by one of us, ten years ago, of *Astrocrinus Benniei,* further examples of this remarkable type have come to hand, and the present state of our knowledge of Blastoid morphology enables us to form a better idea of its structure and systematic position than was possible in 1876.

Some of the figures formerly given in illustration of this species exhibit features

which we have not been able to again illustrate by means of the specimens now before us. Thus, the form and position of the azygos basal was observed in a specimen in which it had been slightly thrust out of place [1], and some imperfect evidence has been obtained as to the nature of the hydrospires. We have previously referred to the possibility of these being lodged partially or entirely within the substance of the radial plates; and this fact is to some extent borne out by the structure of a radial forming a portion [2] of the original collection of *Astrocrinus Benniei*, which is now in the Museum of the Geological Survey of Scotland. Some folds are visible on the interior of this plate, which it is highly probable are the impressions of hydrospires, as shown in our figures (Pl. XX. figs. 4, 18, 20). Reference was also made to a small spine [3], which, although not exhibiting any traces of definite attachment to the specimen to which it adhered, was believed to belong to *A. Benniei*. A closer examination of the ornamenting tubercles has led us to the conclusion that some of the larger ones at any rate were perforate. This fact has been independently observed by our friend Mr. P. Highley whilst engaged in figuring the specimens (Pl. XX. fig. 5). It is not unnatural to suppose, therefore, that the spine previously referred to probably belonged to *A. Benniei*. This view is also supported by the fact that Hambach has described *Granatocrinus granulatus*, Roemer, sp., as possessing perforate tubercles [4], whilst Prof. H. S. Williams and Dr. G. J. Hinde have observed a similar feature in two Crinoids, *Arthroacantha Ithacensis* [5], from the Upper Devonian of New York State, and *Hystricrinus Carpenteri*, from the Middle Devonian of Ontario [6] respectively. We have not had the advantage of a reexamination of the detached ambulacrum [7] figured by one of us in 1876, but ample evidence was then adduced to show the presence of a lancet-plate, side plates, and outer side plates. The form of the calyx varies considerably, as will be evident from our figures on Pl. XX. But the interradius opposite to the azygos ambulacrum is generally much produced (Pl. XX. figs. 9–13), and this, as far as it goes, is one of the points of difference between this species and *A. tetragonus*, which has the three normal interradii tolerably equal in size (Pl. XX. fig. 1). Figs. 7, 8, 14, on the same plate, show, however, that this is sometimes the case in *A. Benniei*. The relation of the deltoids to the radial limbs is well seen in figs. 2, 11, 12, 14–16.

Localities and Horizon. Midlothian and Fife; Shales above No. 1 and No. 2. Limestones of the Lower Carboniferous Limestone group. (Presented by Dr. P. H. Carpenter, F.R.S.)

[1] Quart. Journ. Geol. Soc. 1876, vol xxxii. t. 13. f. 12. [2] *Ibid.* f. 14. [3] *Ibid.* f. 23.

[4] Trans. St. Louis Acad. Sci. 1884, vol. iv. no. 3, p. 543. We figure a fragment of this species for the purpose of showing the tubercles (Pl. VI. fig. 22), but we are not altogether satisfied that they show the "very distinct sockets for the articulation of spines (?)" which are described by Hambach.

[5] "On a Crinoid with Movable Spines." Proc. American Phil. Soc. 1883, pp. 81–88.

[6] "Description of a new Species of Crinoids with Articulating Spines." Ann. & Mag. Nat. Hist. 1885, vol. xv. p. 157. [7] *Loc. cit.* t. 13. f. 17–19.

BIBLIOGRAPHY.

The following works have been consulted during the preparation of the Catalogue.

The generic and specific names which accompany each title are those which were employed by the author in the work referred to, and not those by which the types described therein are now known.

ARCHIAC, E. J. A. d', and VERNEUIL, E. de. "Note sur les Fossiles du Terrain paléozoïque des Asturies." Bull. Soc. Géol. France, 1845, tome ii. pp. 458–482. [*Pentremites Paillettei* and *P. Schul(t)zii*, p. 479.]

AUSTIN, T. and T. "Proposed Arrangement of the Echinodermata particularly as regards the Crinoidea, and a subdivision of the class Adelostella (Echinidæ)." Ann. & Mag. Nat. Hist. 1842, vol. x. pp. 106–113. [*Astracrinites*, p. 110, *Pentremites* and *Orbitremites*, p. 111.]

——. "Descriptions of several new Genera and Species of Crinoidea." *Loc. cit.* 1843, vol. xi. pp. 195–207. [*Astrocrinites*, p. 206.]

BAILY, W. H. "On a new Species of *Orophocrinus* (*Pentremites*), in Carboniferous Limestone, County Dublin." Also Remarks upon *Codaster trilobatus* (McCoy), from Carboniferous Limestone, County Kilkenny. Proc. Roy. Dub. Soc. 1886, vol. v. pt. 1, pp. 31–33, t. 1.

BARRIS, Prof. W. H. "Description of some new Blastoids from the Hamilton Group." Report Geol. Survey Illinois, 1883, vol. vii. pp. 357–364; Proc. Davenport Acad. Nat. Sci. 1885, vol. iv. pp. 88–94.

BARROIS, Dr. C. "Recherches sur les Terrains anciens des Asturies et de la Galice." Mém. Soc. Géol. du Nord, 1882, tome ii. Mém. 1, pp. 630, pl. 20. [*Pentremites Paillettei*, and *P. Schul(t)zii*, p. 225.]

BILLINGS, E. "Figures and Descriptions of Canadian Organic Remains. Crinoidea of the Lower Silurian Rocks of Canada." Decades, Geol. Survey Canada, 1859, no. iv. [*Blastoidocrinus*, p. 18.]

——. "Note on the Structure of the Blastoidea." American Journ. Sci. 1869, vol. xlvii. p. 353; Canadian Nat. & Geol. 1869, vol. iv. p. 89.

——. "Notes on the Structure of the Crinoidea, Cystidea, and Blastoidea." *Loc. cit.* 1869, vol. xlviii. pp. 69–83; *id.* 1870, vol. xlix. pp. 51–58. *Loc. cit.* 1869, vol. iv. pp. 277–293, 426–433; *id.* 1870, vol. v. pp. 180–198; Ann. & Mag. Nat. Hist. 1870, vol. v. pp. 251–266, 409–416; *id.* 1871, vol. vii. pp. 142–158.

BRONN, Dr. H. G. Index Palæontologicus. Nomenclator. 8vo. Stuttgart, 1848. [Abth. 1, *Pentatrematites*, p. 945.]

——. Die Klassen und Ordnungen des Thier-Reichs. 2e Bd. (Actinozoen). 8vo. Leipzig, 1860. [Blastoidea, p. 179.]

CARPENTER, Dr. P. H. "On certain Points in the Morphology of the Blastoidea." Ann. & Mag. Nat. Hist. 1881, vol. viii. pp. 418–424.

Carpenter, Dr. P. H. "Remarks on the Structure and Classification of the Blastoidea." Brit. Assoc. Report for 1881 [1882], pt. 2, p. 634.

——. "Report upon the Crinoidea collected during the Voyage of H.M.S. 'Challenger' during the years 1873–76."—Part. I. Zool. Chall. Exp. 1884, vol. xi. part xxxii. pp. x & 442, pl. 69. [*Blastoidea*, pp. 54, 68, 75, 109, 132, 148, 149, 154, 164, 173, 175, 186, 188–195, 413, 414.]

——. "Further Remarks on the Morphology of the Blastoidea." Ann. & Mag. Nat. Hist. 1885, vol. xv. pp. 277–300.

Conrad, T. A. "Observations on the Silurian and Devonian Systems of the United States, with descriptions of new Organic Remains." Journ. Acad. Nat. Sci. Philad. 1842, vol. viii. pp. 228–280. [*Nucleocrinus*, p. 280.]

——. "Observations on the Lead-bearing Limestone of Wisconsin, and descriptions of a new Genus of Trilobites, and fifteen new Silurian Fossils." Proc. Acad. Nat. Sci. Philad. 1843, pp. 329–334. [*Pentremites truncata*, p. 334.]

Cumberland, G. Reliquiæ Conservatæ, &c. 8vo. Bristol, 1826. [*Mitra*, p. 31.]

Defrance, J. L. M. [Article "Encrinus."] Dict. Sci. Nat. 1819, tome xiv. pp. 461–468. [*Encrina Godoni*, p. 467.]

Dujardin, F., & Hupé, H. Histoire Naturelle des Zoophytes Échinodermes. 8vo. Paris, 1862. [Blastoidea, p. 85.]

Etheridge, R., jr. "On the Occurrence of the genus *Astrocrinites* (Austin) in the Lower Carboniferous Limestone Series of Scotland, with the description of a new Species (*A.* ? *Benniei*), and remarks on the Genus." Quart. Journ. Geol. Soc. 1876, vol. xxxii. pp. 103, pls. xii. & xiii.

——. "Palæontological Notes." Geol. Mag. 1878, vol. v. pp. 117–119. [*Pentremites*, p. 118.]

——. "On the Occurrence of the genus *Pentremites* (Say) in the Carboniferous Limestone Series of the East of Scotland," &c. Proc. Nat. Hist. Soc. Glasgow, 1881, vol. iv. pt. 2, pp. 260–269, pls. 5 & 6.

Etheridge, R., jr., and Carpenter, Dr. P. H. "On certain points in the Morphology of the Blastoidea, with descriptions of some new Genera and Species." Ann. & Mag. Nat. Hist. 1882, vol. ix. pp. 213–252.

——, ——. "Further Remarks on the Morphology of the Blastoidea, with descriptions of a new British Carboniferous Genus, and some new Devonian Species from Spain." *Ibid.* 1883, vol. xi. pp. 225–246.

Fleming, Rev. Dr. J. A History of British Animals, &c. 8vo. Edinburgh, 1828. [*Pentremites*, p. 496.]

Forbes, Prof. E. "On the Cystideæ of the Silurian Rocks of the British Islands." Mem. Geol. Survey Gt. Brit. 1848, vol. ii. pt. 2, pp. 483–538. [*Pentremites* &c., p. 528.]

Fraipont, Dr. J. "Recherches sur les Crinoïdes du Famennien (Devonien supérieur).—Pt. iii." Ann. Soc. Géol. Belgique, 1883–84, tome xi. pp. 105–118, t. 1. [*Pentremites Fraiponti*, p. 114.]

Gaudry, Prof. A. Les Enchaînements du Monde Animal dans les Temps Géologiques. Fossiles Primaires. 8vo. Paris, 1883. [*Blastoidea*, p. 88.]

Gray, Dr. J. E. Synopsis of the Contents of the British Museum. 42nd edit. 12mo. London, 1840. [*Orbitremites*, p. 63.]

Geinitz, Prof. H. B. Grundriss der Versteinerungskunde. 8vo. 2 Bde. Dresden-Leipzig 1845–46. [*Pentremites,* Bd. 2, p. 558.]

Goldfuss, Dr. A. Petrefacta Germaniæ. Folio. Theil 1. Düsseldorf, 1826. [*Pentremites,* p. 160.]

Gurley, W. F. E. New Carboniferous Fossils. Bulletin No. 2, 1884, pp. 1–12. 8vo. Danville, Illinois, U.S. [*Troostocrinus Wachsmuthi,* p. 1.]

Hall, Prof. J. Palæontology of New York. 4to. Vol. ii. Albany, 1851. [*Stephanocrinus,* p. 212, t. 48, p. 351, t. 83, Suppl.]

——. "Descriptions of new Species of Fossils from the Carboniferous Limestone of Indiana and Illinois." Trans. Albany Inst. 1858, vol. iv. pp. 1–36. [*Pentremites,* p. 4.]

——. Report on the Geological Survey of the State of Iowa. 4to. Vol. i. pt. 2. Iowa, 1858. [*Pentremites,* pp. 405, 606, 655, and 692.]

——. "Descriptions of new Species of Crinoidea from the Carboniferous Rocks of the Mississippi Valley. Boston Journ. Nat. Hist. 1861, vol. vii. No. 2, pp. 261–328. [*Codaster Whitei,* p. 327.]

——. "Preliminary notice of some of the Species of Crinoidea known in the Upper Helderberg and Hamilton Groups of New York." 15th Annual Report, New York, State Cab. Nat. Hist. 1862, pp. 115–153. [*Nucleocrinus,* p. 144; *Pentremites,* p. 149; *Eleutherocrinus,* p. 151; *Codaster,* p. 152.]

——. "The Fauna of the Niagara Group in Central Indiana." 28th Report, *loc. cit.* (Mus. Edit.), 1879, pp. 99–199. [*Stephanocrinus gemmiformis,* p. 146.]

——. "Descriptions of the Species of Fossils found in the Niagara Group at Waldron, Indiana." Collett's 11th Ann. Report, Dept. Geol. & Nat. Hist. Indiana for 1881 [1882], pp. 217–401. [*Stephanocrinus gemmiformis,* p. 279; *Codaster pulchellus,* p. 280; *C. pentalobus,* p. 280.]; Trans. Albany Inst. 1883, vol. x. pp. 57–76.

——. [Descriptions of Fossils from the Carboniferous Limestone of Spergen Hill, Indiana.] 12th Ann. Rep. *loc. cit.* for 1882 [1883], pp. 319–375. [*Pentremites Koninckana,* p. 322; *P. conoideus,* p. 323.]

Hall, Prof. J., and Whitfield, R. P. "Descriptions of Invertebrate Fossils, mainly from the Silurian System." Report Geol. Survey Ohio, 1875, vol. ii. pt. 2, pp. 65–179. [*Pentremites subcylindrica,* p. 129.]

Hambach, G. "Contribution to the Anatomy of the genus *Pentremites,* with descriptions of new Species." Trans. St. Louis Acad. Sci. 1880, vol. iv. No. 1, pp. 145–160, pls. A & B.

——. "Notes about the Structure and Classification of the Pentremites." *Loc. cit.* 1884, vol. iv. No. 3, pp. 537–547.

——. "Descriptions of new Palæozoic Echinodermata." *Loc. cit.* pp. 548–554, pls. C & D. [*Pentremites Sampsoni,* p. 551; *P. gemmiformis,* p. 553; *Codonites campanulatus,* p. 553.]

Haughton, Rev. S. "On a new Carboniferous Echinoderm [*Pentephyllum*] from the County of Limerick." Nat. Hist. Review, 1859, vol. vi. pt. 2, p. 511; Journ. Geol. Soc. Dublin, 1859, vol. viii. pt. 2, p. 184, t. 29 (12). f. *a–d.*

Hoernes, Prof. K. "Elemente der Palaeontologie (Palaeozoologie)." 8vo. Leipzig, 1884. [Blastoidea, p. 126.]

Koninck, Prof. L. G. de. Description des Animaux fossiles qui se trouvent dans le Terrain carbonifère de Belgique. 2 vols. & Suppl. 4to. Liége, 1842–51. [*Pentremites,* p. 35.]

Koninck, Prof. L. G. de, et Le hon, H. "Recherches sur les Crinoïdes du Terrain carbonifère de la Belgique." Mém. Acad. Roy. Belgique, 1854, tome xxvii. Mém. 3, pp. 215, pls. 7. [Blastoidea, p. 189.]

Ludwig, Prof. H. Die Bursae der Ophiuriden und deren Homologen bei den Pentatrematiten. Nachr. kgl. Gesellsch. Wissensch. zu Göttingen. 1878. No. 6, pp. 215–220.

——. "Beiträge zur Anatomie der Ophiuren." Zeitschr. f. wiss. Zool. 1878, Bd. xxxi. pp. 346–390. [Blastoidea, p. 387.]

Lyon, S. S. "Palæontological Report." Owen's 3rd Report, Geol. Survey Kentucky, 1856–57 [1857], pp. 465–498. [*Pentremites*, p. 468; *Olivanites*, p. 487.]

——. "Descriptions of four new Species of Blastoidea from the Subcarboniferous Rocks of Kentucky." Trans. St. Louis Acad. Sci. 1860, vol. i. No. 4, pp. 628–634, pl. 20.

Lyon, S. S., and Casseday, S. A. "A Synonymic List of the Echinodermata of the Palæozoic Rocks of the United States." Proc. American Acad. 1860, vol. iv. pp. 282–304.

M'Coy, Prof. F. A Synopsis of the Characters of the Carboniferous Limestone Fossils of Ireland. 4to. Dublin, 1844. [*Pentremites*, p. 174.]

——. "On some new Palæozoic Echinodermata." Ann. & Mag. Nat. Hist. 1849, vol. iii. pp. 244–254. [*Pentremites* and *Codaster*, pp. 249, 250.]

——. Contributions to Palæontology. 8vo. London, 1854. [*Pentremites* and *Codaster*, p. 111.]

——. Systematic Description of the British Palæozoic Fossils, &c. 4to. Fasc. 1. Cambridge, 1851. [Blastoidea, fasc. 1, 1851, p. 122.]

Mallada, L. "Sinopsis de las Especies fósiles que se han encontrado en España." Bol. Com. Mapa Geol. España, 1875, tomo ii. pp. 160; *Ibid.* 1877, tomo iv. lám. 11, 12, 17, &c. [*Pentremites Paillettei* and *P. Schulzii*, p. 78.]

Meek, F. B. "Palæontological Report." Hayden's 6th Ann. Report U. S. Geol. Survey Territories for 1872 [1873], pp. 429–518. [*Pentremites Bradleyi*, p. 470; *P. subconoideus*, p. 471.]

——. "Notes on some of the Fossils figured in the recently issued Fifth Volume of the Illinois State Geological Report." American Journ. Sci. 1874, vol. vii. pp. 369–376. [Blastoidea, p. 372.]

Meek, F. B., and Worthen, A. H. "Descriptions of new Palæozoic Fossils from Illinois and Iowa." Proc. Acad. Nat. Sci. Philad. 1861, pp. 128–148. [Blastoidea, p. 141.]

——, ——. "Contributions to the Palæontology of Illinois and other Western States." *Loc. cit.* 1866, pp. 251–275. [*Granatocrinus*, p. 257.]

——, ——. "Descriptions of Invertebrata." Report Geol. Survey Illinois, 1866, vol. ii. [*Granatocrinus*, p. 274.]; *Loc. cit.* 1868, vol. iii. [*Granatocrinus*, p. 496.]; *Loc. cit.* 1873, vol. v. [*Codonites*, p. 463 &c.]; *Loc. cit.* 1875, vol. vi. [*Pentremites*, p. 521 &c.]

——, ——. "Remarks on some types of Carboniferous Crinoidea, with descriptions of new Genera and Species, &c. Proc. Acad. Nat. Sci. Philad. 1868, pp. 335–359. [*Pentremites* (*Troostocrinus*?) *Woodmani*, p. 356.]

——, ——. "Remarks on the Blastoidea, with descriptions of new Species." *Loc. cit.* 1869, pp. 83–91. [*Granatocrinus*, p. 88.]

Miller, J. G. A Natural History of the Crinoidea, or Lily-shaped Animals, &c. 4to. Bristol, 1821. [*Platycrinites pentangularis*, p. 83.]

MILLER, S. A. "Descriptions of twelve new fossil Species, and remarks upon others." Journ. Cincinnati Soc. Nat. Hist. 1879, vol. ii. No. 3, pp. 104–118. [*Stephanocrinus Osgoodensis*, p. 116.]

——. The American Palæozoic Fossils. A Catalogue of Genera and Species. Eds. 1 & 2. 8vo. Cincinnati, 1877 and 1883.

——. "Description of two new Species from the Niagara Group, and five from the Keokuk Group." Journ. Cincinnati Soc. Nat. Hist. 1880, vol. ii. No. 4, pp. 254–259. [*Codaster gratiosus*, p. 257.]

MILLER, S. A., and DYER, C. B. "Contributions to Palæontology." Journ. Cincinnati Soc. Nat. Hist. 1878, vol. i. No. 1, pp. 24–39. [*Codaster pulchellus*, p. 35.]

MONTGOMERY, Prof. H. "A Blastoid found in the Devonian Rocks of Ontario." Canadian Nat. & Geol. 1881, vol. x. pp. 80–84. [*Nucleocrinus Canadensis.*]

MORRIS, Prof. J. A Catalogue of British Fossils. Eds. 1 & 2. 8vo. London, 1843 & 1854. [*Astrocrinus* and *Pentremites*, pp. 72 & 86.]

MÜLLER, Prof. J. "Ueber den Bau des *Pentacrinus Caput-Medusæ*." Phys. Abhandl. K. Akad. Wissensch. Berlin, 1841 [1843], pp. 177–248, pls. 1–6. [Blastoidea, p. 229.]

MÜNSTER, G. von. "Beschreibung einiger neuen Crinoideen aus der Uebergangs-Formation." Beiträge zur Petrefactenkunde, 1843. Heft i. pp. 31–34. [*Pentremites Puzos*, p. 31.]

MUNIER-CHALMAS, E. "Mollusques nouveaux des Terrains paléozoïques. des Environs de Rennes." Journ. Conchyliol. 1876, tome xvi. pp. 102–109. [*Belemnocrinus Cottaldi*, p. 105.]

ŒHLERT, D. "Crinoïdes nouveaux du Dévonien de la Sarthe et de la Mayenne." Bull. Soc. Géol. France, 1882, tome x. pp. 352–363, t. 8. [*Belocrinus Cottaldi*, p. 362.]

ORBIGNY, A. d'. Prodrome de Paléontologie stratigraphique. 3 tomes. 12mo. Paris, 1849. [Tome i. *Pentremites*, pp. 102 & 154; *Pentremitidea*, p. 102.]

——. Cours élémentaire de Paléontologie et de Géologie stratigraphique. 2 tomes (and tables). 8vo. and 4to. Paris, 1849–52. [Tome ii. fas. 1. 1852, *Pentremites* and *Pentremitidæa*, p. 139.]

OWEN, D. D. "Regarding Human Foot-prints in solid Limestone." American Journ. Sci. 1842, vol. xliii. pp. 14–32. [*Pentremites pyriformis*, p. 20.]

OWEN, D. D., and SHUMARD, B. F. "Descriptions of fifteen new species of Crinoidea from the Sub-Carboniferous Limestone of Iowa, collected during the U. S. Geological Survey of Wisconsin, Iowa, and Minnesota in the years 1848–49. Journ. Acad. Nat. Sci. Philad. 1850, vol. ii. pt. 1, pp. 57–70, pl. 7. [*Pentremites*, p. 64.]

——, ——. "Descriptions of one new Genus and twenty-two new Species of Crinoidea from the Sub-Carboniferous Limestone of Iowa." Wisconsin, Iowa, and Minnesota Geol. Report, 1852, pp. 587–598. [*Pentremites*, p. 591.]

PARKINSON, J. Organic Remains of a former World, &c. 3 vols. 4to. London, 1808–20 [Asterial Fossil, vol. ii. p. 235.]

PHILLIPS, Prof. J. Illustrations of the Geology of Yorkshire. Pt. 2. The Mountain Limestone District. 4to. London, 1836. [*Pentremites*, p. 207.]

——. Figures and Descriptions of the Palæozoic Fossils of Cornwall, Devôn, and West Somerset. 8vo. London, 1841. [*Pentremites ovalis*, p. 29.]

PICTET, Prof. F. J. Traité de Paléontologie. 2^{me}. éd. 4 tomes. 8vo. Paris, 1853–57. [Blastoidea, vol. iv. p. 292.]

PORTLOCK, Col. J. E. Report on the Geology of the County of Londonderry, and of parts of Tyrone and Fermanagh, &c. 8vo. Dublin, 1843. [*Pentremites ovalis*, p. 351.]

QUENSTEDT, Prof. A. Handbuch der Petrefactenkunde. 8vo. Tübingen, 1852. *Pentremites*, p. 628; 3rd Edition. 8vo. Tubingen, 1885. Lief. 20. [Blastoidea, pp. 971–973.]

——. Petrefactenkunde Deutschlands. Bd. iv. Die Asteriden und Encriniden, &c. 8vo. Leipzig, 1874–76. [Blastoidea, p. 711.]

ROEMER, Prof. F. [Sur une Pentrémite des Etats-Unis.] Bull. Soc. Géol. France, 1848, tome v. p. 296. [*Pentremites florealis.*]

——. "Ueber gegliederte, aus Kalk-Stückchen zusammengesetzte Tentakeln oder Pinnulae auf den sogenannten Ambulakral-Feldern der Pentremiten." Neues Jahrbuch f. Mineral. 1848, pp. 292–296.

——. "Ueber *Stephanocrinus*, eine fossile Crinoiden-Gattung aus der Familie der Cystideen." Archiv f. Naturgesch. 1850, Jahrg. xvi. Bd. i. pp. 365–375, pl. 5.

——. "Monographie der fossilen Crinoidenfamilie der Blastoideen, und der Gattung *Pentatrematites* im Besonderen." *Loc. cit.* 1851, Jahrg. xvii. Bd. i. pp. 323–397, pls. 4–8.

——. "Palaeo-Lethaea: Kohlen-Periode (Silur-, Devon-, Kohlen- und Zechstein-Formation)." Bronn's Lethæa Geognostica. Drit. Aufl. 1851–56. I Bd. 2 Theil. 1852. [Blastoidea, p. 278.]

——. Die Silurische Fauna des Westlichen Tennessee. 4to. Breslau, 1860. [*Pentremites Reinwardtii*, p. 60.]

ROFE, J. "Notes on some Echinodermata from the Mountain Limestone," &c. Geol. Mag. 1865, vol. ii. pp. 245–252, pl. 8. [*Pentremites*, p. 248; *Codaster*, p. 250.]

SANDBERGER, G. and F. Die Versteinerungen der Rheinischen Schichtensystems in Nassau. 4to. Wiesbaden, 1850–56. [*Pentatrematites*, p. 402.]

SAY, T. "Observations on some Species of Zoophytes, Shells, &c., principally fossil." American Journ. Sci. 1820, vol. ii. pp. 34–45. [*Pentremites*, p. 36.]

——. "On two Genera and several Species of Crinoidea." Journ. Acad. Nat. Sci. Philad. 1825, vol. iv. pt. 2, pp. 289–296; Zool. Journ. 1825, vol. ii. No. 7, pp. 311–315. [*Pentremites florealis*, *P. pyriformis*, and *P. globosa*.]

SCHLOTHEIM, E. F. von. Die Petrefactenkunde, &c. Text, 8vo. Atlas, 4to. Gotha, 1820. [*Encrinites florealis*, p. 339.]

SCHMIDT, Mag. F. "Miscellanea Silurica, II. Ueber einige neue und wenig bekannte Baltisch-Silurische Petrefacten." Mém. Acad. Imp. Sci. St. Pétersb. 1874, Tome xxi. Mém. ii. pp. 47, pls. 4. [*Blastoidocrinus*, p. 27.]

SCHULTZE, Dr. L. "Monographie der Echinodermen des Eifler Kalkes." Denkschr. K. Akad. Wissensch. Wien, 1867, Bd. xxvi. Abth. 2, pp. 113–230, pls. 1–13[1]. [*Pentremites*, p. 223.]

SEEBACH, Prof. K. von. "Ueber *Orophocrinus* ein neues Crinoideengeschlecht aus der Abtheilung der Blastoideen." Nachr. kgl. Gesellsch. Wissensch. zu Göttingen, 1864, pp. 110, 111.

SHUMARD, Dr. B. F. ["Palæontological Report."] Swallow's 1st and 2nd Ann. Reports Geol. Survey Missouri, 1855, pt. 2, pp. 185–187. [*Pentremites*, p. 185.]

——. "Descriptions of New Species of Blastoidea from the Palæozoic Rocks of the Western States, with some observations on the Structure of the Summit of the Genus *Pentremites*." Trans. St. Louis Acad. Sci. 1858, vol. i. No. 2, pp. 238–248, pl. 9.

[1] The separate copies of this work are dated 1866.

SHUMARD, Dr. B. F. "Descriptions of new Palæozoic Fossils." *Loc. cit.* 1863, vol. ii. No. 1, pp. 108–113. [*Elæacrinus*, p. 111.]

——. "A Catalogue of the Palæozoic Fossils of North America. Part I. Palæozoic Echinodermata." *Loc. cit.* 1865, vol. ii. No. 2, pp. 334–407.

SHUMARD, Dr. B. F., and YANDELL, Dr. L. P. "Notice of a new Fossil Genus [*Eleutherocrinus*] belonging to the Family Blastoidea, from the Devonian Strata near Louisville, Kentucky." Proc. Acad. Nat. Sci. Philad. 1856, pp. 73–75, pl. 2.

SOWERBY, G. B. "Note [on two new Genera and several Species of Crinoidea], together with a description of a new Species of *Pentremites*." Zool. Journ. 1825, vol. ii. No. 7, pp. 316–318.

——. "On some new Species of *Pentatrematites*." *Loc. cit.* 1828, vol. iv. No. 13, pp. 89–91.

——. "On *Pentatrematites orbicularis*, [*P.*] *acuta*, and [*P.*] *pentangularis*." *Loc. cit.* 1834, vol. v. No. 20, p. 456.

STEININGER, J. "Die Versteinerungen des Uebergangsgebirge der Eifel." Jahresb. Schul-Cursus, 1848–49, Gymnas. zu Trier, 1849. [*Pentatrematites gracilis*, p. 19.]

SWALLOW, G. C. "Descriptions of some new Fossils from the Carboniferous and Devonian Rocks of Missouri." Trans. St. Louis Acad. Sci. 1863, vol. ii. No. 1, pp. 81–100. [*Pentremites Missouriensis*, p. 81.]

TROOST, Dr. G. "On the *Pentremites Reinwardtii*, a new fossil, with remarks on the Genus *Pentremites* (Say)," &c. Trans. Geol. Soc. Pennsyl. 1835, vol. i. pt. 2, pp. 224–231, t. 10.

——. Fifth Geological Report to the 23rd General Assembly of the State of Tennessee, made November 1839. 8vo. Nashville, 1840. [*Pentremites*, p. 57.]

——. Sixth Geological Report to the 24th General Assembly of the State of Tennessee, made October 1841. 8vo. Nashville, 1841. [*Pentremites*, p. 20.]

——. [Genera and Species of Fossil Crinoidea which occur in Tennessee.] American Journ. Sci. 1849, vol. viii. p. 419; Proc. American Assoc. Adv. Sci. for 1849 [1850], pp. 59–64.

VERNEUIL, E. de. [Sur une nouvelle Espèce de Pentrémite.] Bull. Soc. Géol. France, 1844, tome i. p. 213. [*P. Paillettei.*]

——. "Ueber *Pentremites Dutertrii*." L'Institut. 1st Sect. Sciences, Math., Phys., et Nat. 1844, no. 547, p. 216.

WACHSMUTH, C. "On a new Genus and Species of Blastoids; with observations upon the structure of the basal plates in *Codaster* and *Pentremites*." Report Geol. Survey, Illinois, 1883, vol. vii. pp. 346–357; Proc. Davenport Acad. Nat. Sci. 1885, vol. iv. p. 76.

WACHSMUTH, C., and SPRINGER, F. "Revision of the Palæocrinoidea." Parts I. II. & III. (First Section). Proc. Acad. Nat. Sci. Philad. 1879, pp. 226–378 [Blastoidea, p. 230]; *id.* 1881, pp. 177–414 [Blastoidea, pp. 206, 207]; *id.* 1885, pp. 225–359 [Blastoidea, pp. 232, 242–244].

WHIDBORNE, Rev. G. F. "*Pentremites* in the Middle Devonian of Devon." Geol. Mag. 1881, vol. viii. p. 288.

WHITE, Dr. C. A. "Description of new Species of Fossils from the Devonian and Carboniferous Rocks of the Mississippi Valley." Proc. Boston Soc. Nat. Hist. 1862, vol. ix. pp. 8–33. [*P. sirius*, p. 20.]

——. "Observations on the Summit Structure of *Pentremites*, the Structure and Arrangement of certain Parts of Crinoids, and Descriptions of New Species from the Carboniferous Rocks at Burlington, Iowa." Boston Journ. Nat. Hist. 1863, vol. vii. No. 4, pp. 481–506.

——. "Report upon the Invertebrate Fossils collected in portions of Nevada, Utah, Colorado, New Mexico, and Arizona, by Parties of the Expeditions of 1871, 1872, 1873, and

1874." Wheeler's Report Geogr. & Geol. Explor. & Surveys West of the 100th Meridian. 1875. Vol. iv. part i. pp. 219. [*Granatocrinus lotoblastus*, p. 80.]

WHITE, Dr. C. A. "Palæontological Papers. No. 11. Remarks upon certain Carboniferous Fossils from Colorado, Arizona, Idaho, Utah, and Wyoming," &c. Bull. U. S. Geol. & Geogr. Survey Territories, 1879, vol. v. No. 2, pp. 209–221. [*Granatocrinus lotoblastus* ?, p. 212.]

——. "Palæozoic Fossils of the Indiana Rocks." Collett's 2nd Ann. Report Dept. Stat. & Geol. Indiana, for 1880 [1880], pp. 471–522. [*Pentremites*, p. 511.]

WHITFIELD, R. P. "On the Fauna of the Lower Carboniferous Limestones of Spergen Hill, Indiana, with a Revision of the descriptions of its Fossils hitherto published, and Illustrations of the species from the Original Types." Bull. American Mus. Nat. Hist. 1882, vol. i. No. 3, pp. 39–97. [*Pentremites*, p. 43.]

YANDELL, Dr. L. P. [Sur une Pentrémite des Etats-Unis.] Bull. Soc. Géol. France, 1848, tome v. p. 296.

——. "On the Distribution of the Crinoidea in the Western States." Proc. American Assoc. Adv. Sci. 1851, pp. 229–235.

YANDELL, Dr. L. P., and SHUMARD, Dr. B. F. Contributions to the Geology of Kentucky. 8vo. Louisville, 1847. [*Pentremites*, pp. 6 & 12.]

ZITTEL, Prof. K. A. Handbuch der Palæontologie. 1879. i. Bd. 3 Lief. [Blastoidea, p. 427.]

GENERAL INDEX.

The figures in dark type indicate the page on which the genus or species is first described.

The names of genera and species which are regarded as synonyms or as invalid are distinguished by an asterisk (*).

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EXPLANATION OF THE PLATES.

NOTE.—In the following Explanations the page on which each species that is represented in the National Collection is described, is given immediately after the specific name. There is also a reference, after each figure, to the page which contains an exposition of the most important structural characters that are illustrated by the figure in question. In a few cases there is no special reference to a figure in the text; and the number of the page following its explanation is either that of *the specific diagnosis*, or of one containing a description, of structural peculiarities, which is more or less illustrated by the figure in question.

Unless otherwise stated the specimens figured are in the National Collection.

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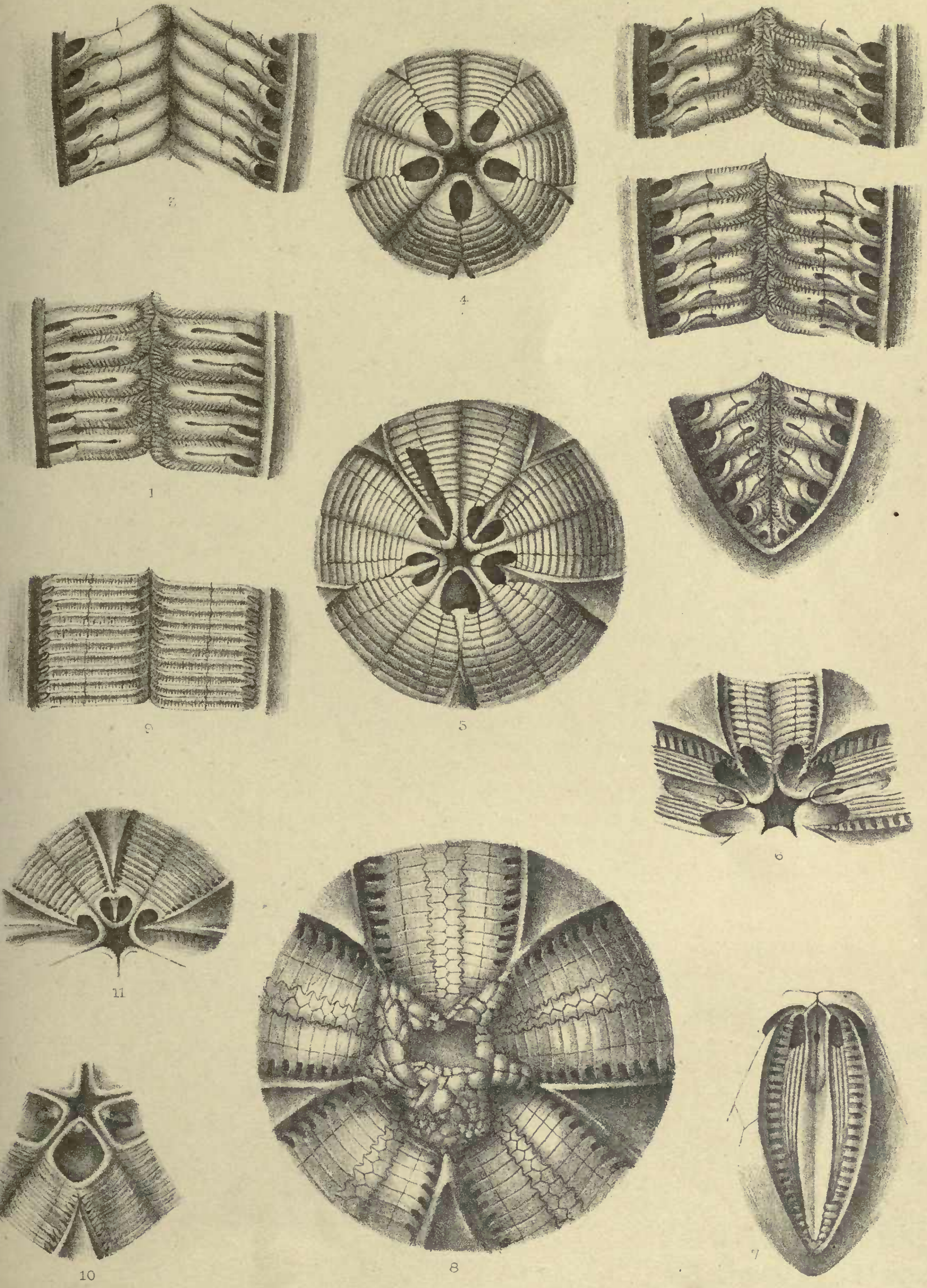

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Pentremites.

PLATE II.

PENTREMITES GODONI, *Defrance*, sp., p. 157.

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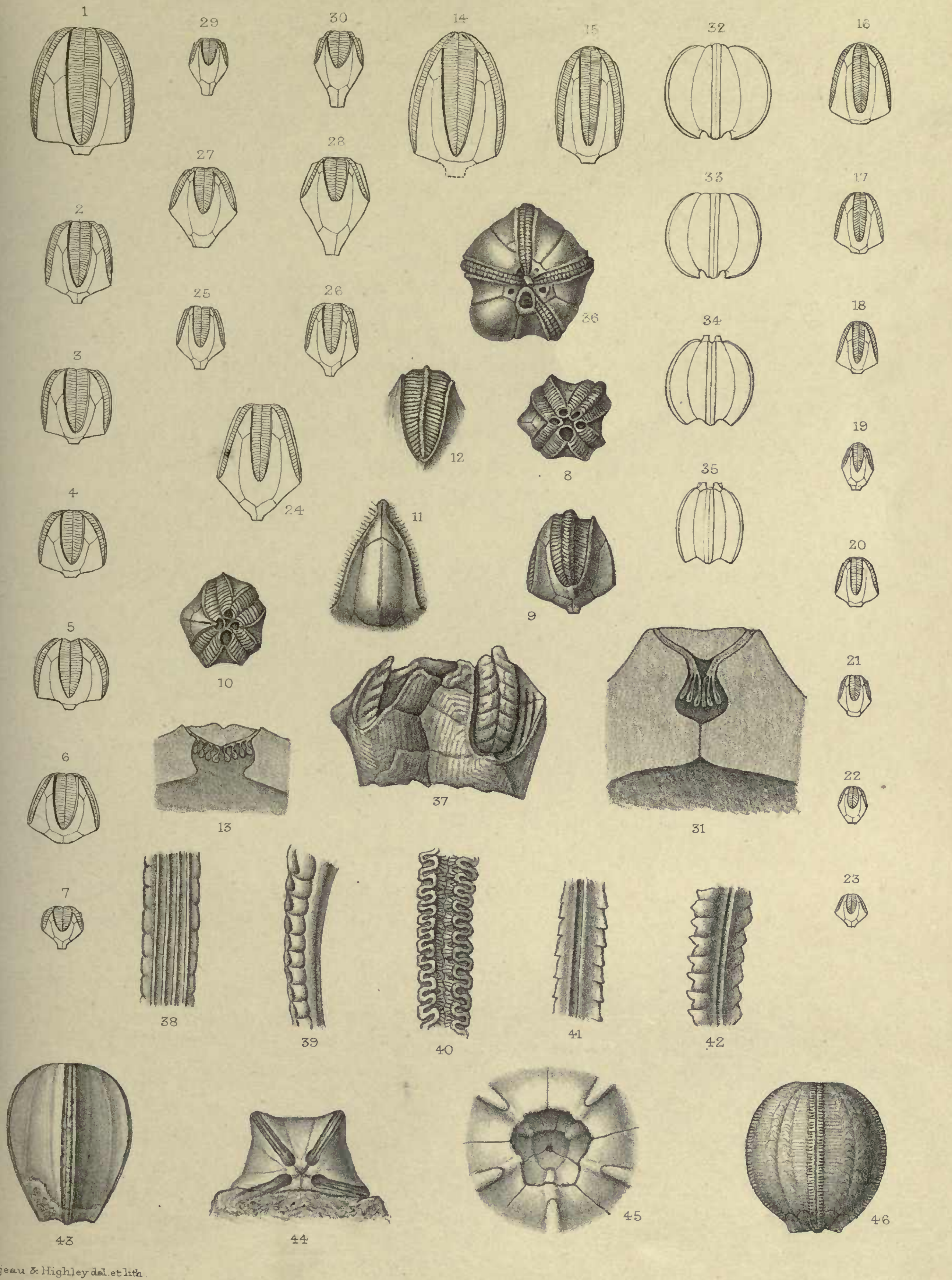

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Pentremites. Granatocrinus. Phænoschisma.
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Schizoblastus Sayi, *Shumard*, sp., p. 224.

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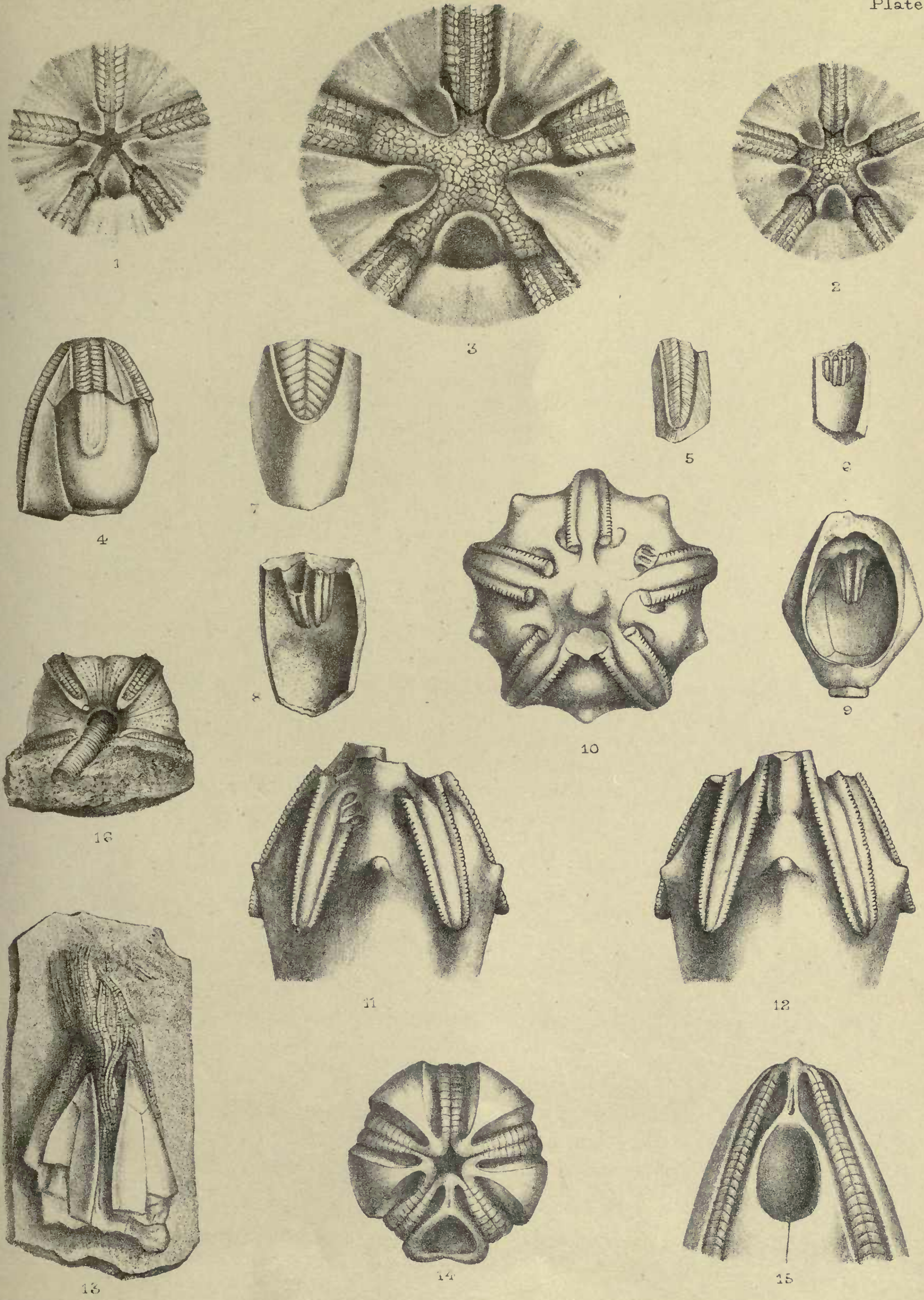

Berjeau & Highley del. et lith.

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Schizoblastus. Pentremites. Troostocrinus. Granatocrinus.

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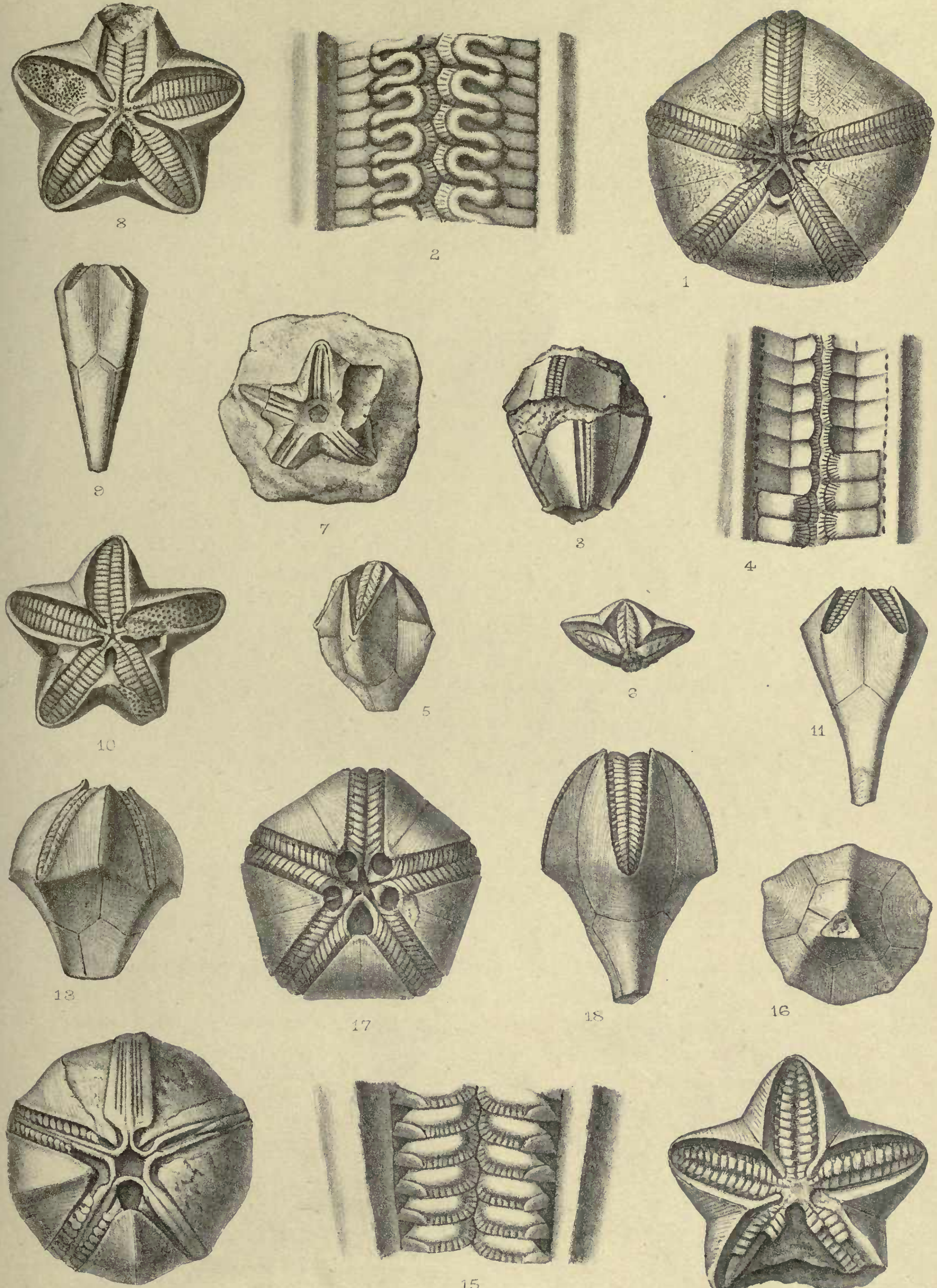

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Mesoblastus. Phænoschisma. Pentremitidea.

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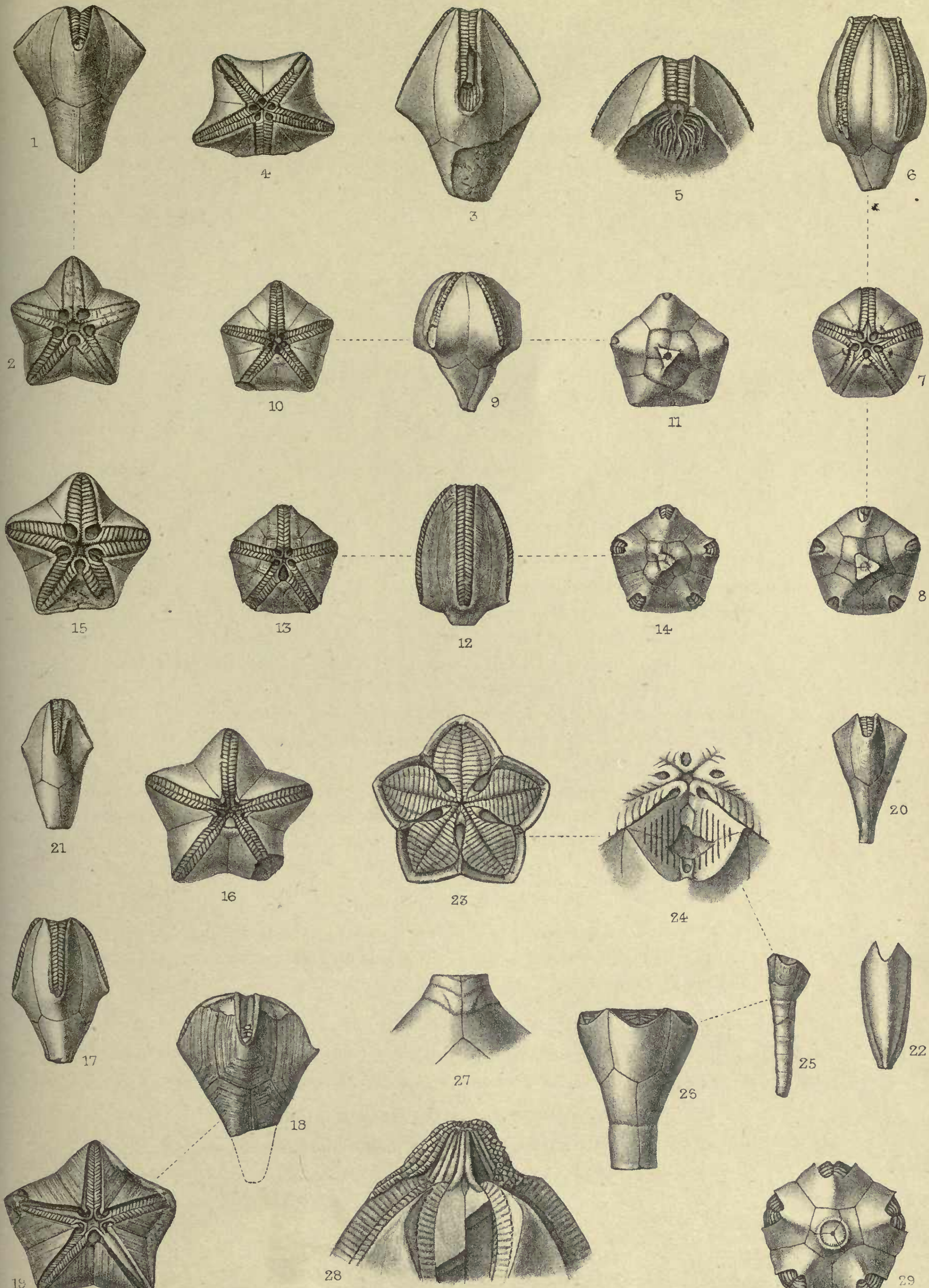

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Pentremites. Pentremitidea.
Cryptoschisma & Troostocrinus.

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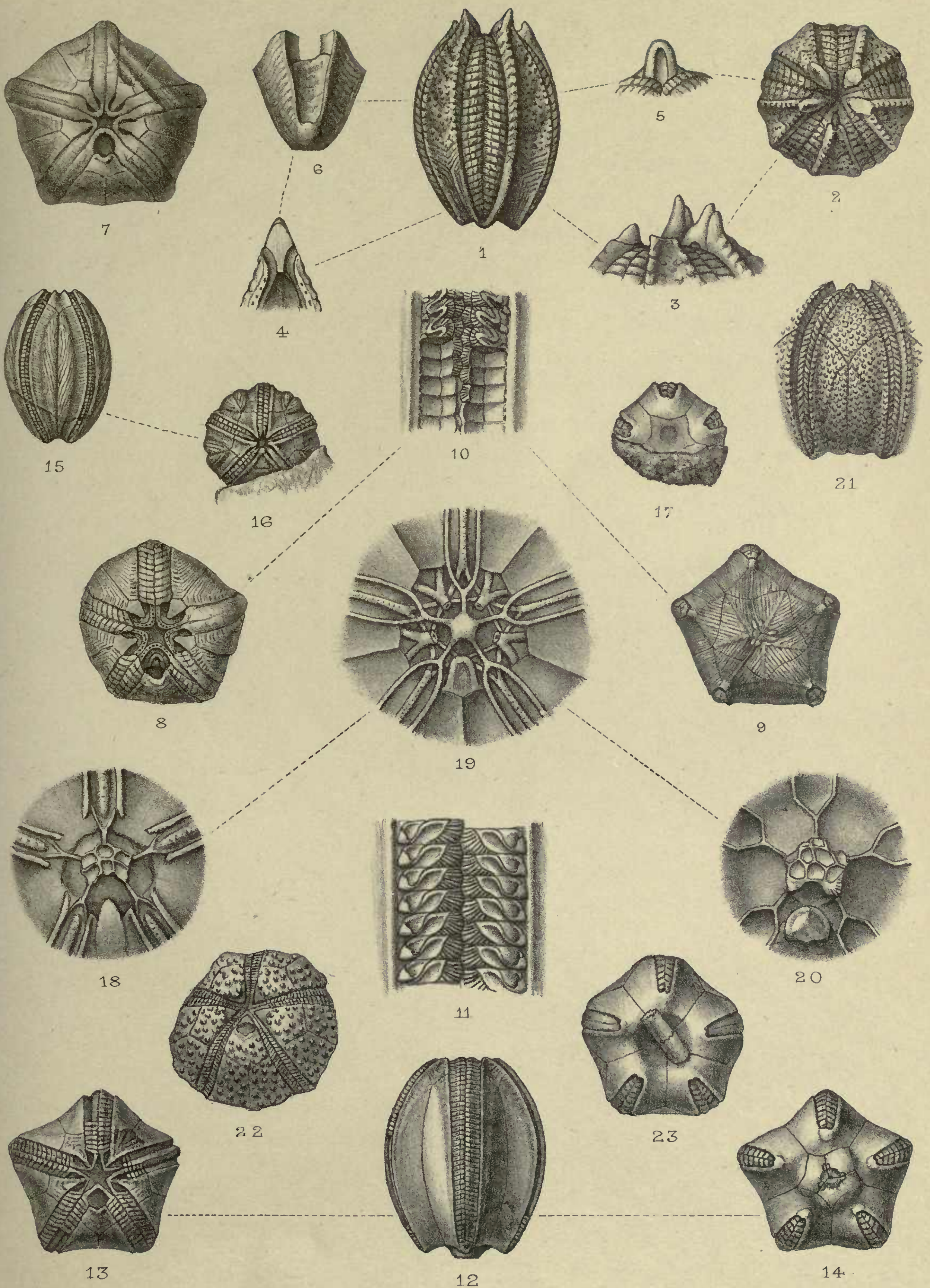

Berjeau & Highley del. et nat.

West, Newman & Co. imp.

Mesoblastus. Heteroblastus. Granatocrinus. Schizoblastus.

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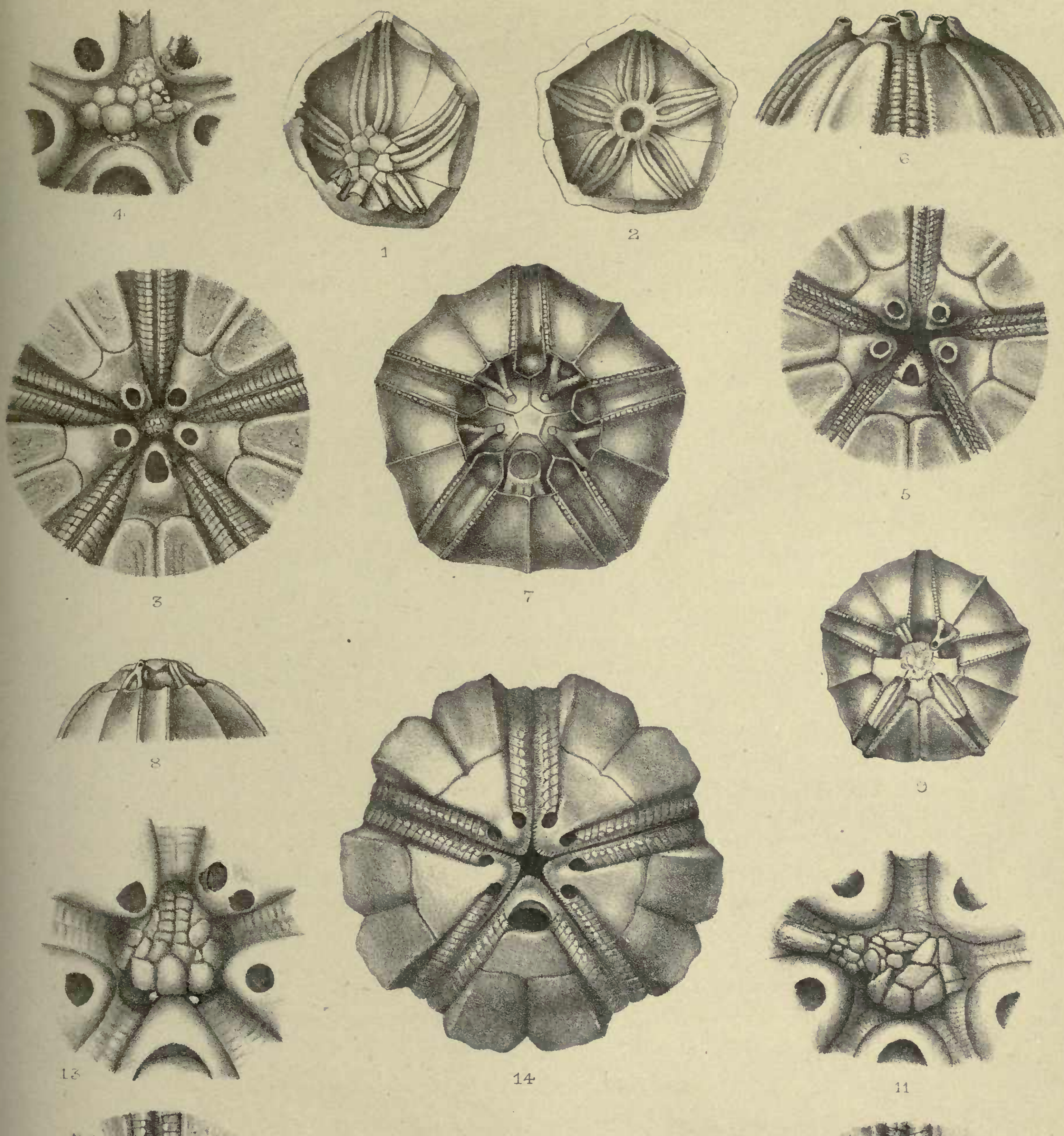
Fig. 7.	The summit of an internal siliceous cast, showing the union of the hydrospire-canals before they reach the spiracles. Subcarboniferous, Iowa. *Coll. Wachsmuth.* ×3.	53
Fig. 8.	Radial view of a similar cast, on which portions of two deltoids and two lancet-plates are still preserved. Subcarboniferous, Iowa. *Coll. Wachsmuth.* ×2 . .	53
Fig. 9.	Summit view of the same cast. ×2.	53
Fig. 10.	The summit of an entire specimen, with the peristome closed by plates. Subcarboniferous, Iowa. *Coll. Wachsmuth.* ×2	67
Fig. 11.	The oral centre of the same individual, enlarged to show the summit-plates. ×10 .	75
Fig. 12.	The summit of another specimen, with a closed peristome and separate spiracle-openings in the left anterior deltoid. Subcarboniferous, Iowa. *Coll. Wachsmuth.* ×4	105
Fig. 13.	The oral centre of this specimen, showing the orocentral surrounded by four (or perhaps six) proximals, with the first covering-plates of the anterior ambulacrum resting against the front pair. ×10	75

Cryptoblastus melo, *O. & S.*, sp., p. 232.

Fig. 14.	Summit view of a good specimen, showing the decagonal, lobate outline, the sunken ambulacra, and the anal spiracle. Subcarboniferous, Iowa. *Coll. Wachsmuth.* ×6	109
Fig. 15.	Portion of the summit of a weathered specimen which has lost most of the side plates, so that the hydrospire-plates and pores are exposed. Subcarboniferous, Iowa. *Coll. Wachsmuth.* ×6	109



Berjeau & Highley del. et lith.

West, Newman & Co. imp.

Granatocrinus. Cryptoblastus.

PLATE VIII.

Mesoblastus elongatus, *G. B. Sby.*, sp., p. 186.

Page

Fig. 1. Radial view of the calyx, with the long and broad ambulacra and small deltoids. Carboniferous Limestone, Lancashire. ×2 11

Fig. 2. Portion of a radial view of the apex taken at an oblique angle, so as to show the divided spiracles. ×4 104

Fig. 3. Basal view of the same specimen. ×2 15

Fig. 4. Summit view of the same, with the divided spiracles. ×2 104

Mesoblastus Sowerbii, *E. & C.*, p. 187.

Fig. 5. Portion of a much enlarged ambulacrum, showing the barely visible lancet-plate, the side and outer side plates, the pinnule-sockets, and the hydrospire-pores. Carboniferous Limestone, Lancashire. ×10 60

Fig. 6. Interradial view of a portion of the summit seen obliquely. Carboniferous Limestone, Lancashire. ×4 49

Mesoblastus angulatus, *G. B. Sby.*, sp., p. 185.

Fig. 7. Interradial view, showing the very large radials and small deltoid plates. Carboniferous Limestone, Lancashire. ×$1\frac{1}{2}$ 30

Fig. 8. Basal view of the same specimen, showing the very contracted base and the small central depression lodging the basal plates. ×$1\frac{1}{2}$ 15

Schizoblastus Rofei, *E. & C.*, p. 228.

Fig. 9. Summit view, showing the double spiracles and the highly ornate calyx. Carboniferous Limestone, Ireland. ×6 110

Fig. 10. Interradial view of the same specimen, showing the form of the deltoid plates, and the position of the radio-deltoid suture. ×6 29

Fig. 11. Portion of an ambulacrum of the same individual. ×24 62

Granatocrinus McCoyi, *E. & C.*, p. 252.

Fig. 12. Summit view, showing the large spiracles with thickened margins. Carboniferous Limestone, Lancashire. ×8 107

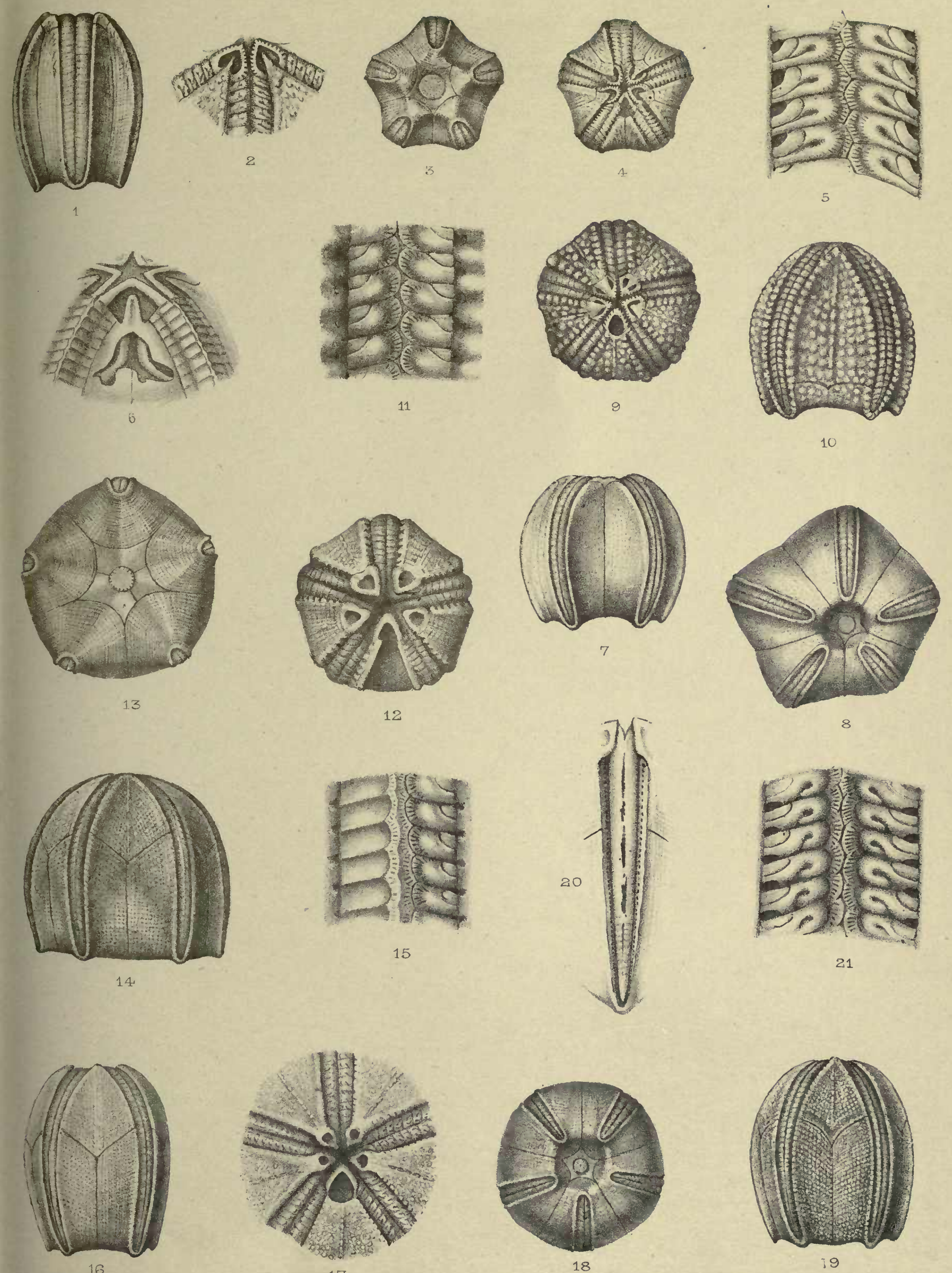
Granatocrinus campanulatus, *McCoy*, sp., p. 251.

Fig. 13. Inferior aspect of the calyx, showing the broad, almost flat base, and the large columnar facet. Carboniferous Limestone, Lancashire. ×5 15

Fig. 14. Interradial view, showing the form of the calyx, and the position of the radio-deltoid suture. ×5 25

Fig. 15. Portion of an ambulacrum, showing the median groove of the lancet-plate, the side and outer side plates in position on the right, and on the left their impressions on the upper surface of the lancet-plate. ×20 49

Granatocrinus ellipticus, *G. B. Sby.*, sp., p. 253.



Berjeau & Highley del. et lith.

West, Newman & C°. imp.

Mesoblastus. Granatocrinus. Schizoblastus.

PLATE IX.

GRANATOCRINUS DERBIENSIS, *G. B. Sby.*, sp., p. 250.

Page

Fig. 1. Interradial view, showing the enormously large deltoid plates and the position of the nearly horizontal radio-deltoid suture. Carboniferous Limestone, Lancashire. ×4 125

Fig. 2. Interradial view of a rather more globose variety, in which the radial plates are larger and the radio-deltoid suture higher. ×4 12

Fig. 3. Inferior aspect of the same specimen, with the converging apices of the ambulacra, the whole of the radial plates exposed to view, and the central depression. ×5 . 15

Fig. 4. A similar view of another example, with shorter ambulacra, the radial plates smaller, and the calyx more highly ornate 12

Fig. 5. Portion of a summit view, showing the spiracles, with the thickened prominences at their outer margins. ×6 107

Fig. 6. A still more globose variety seen in interradial view, with a very low radio-deltoid suture. ×4 29

Fig. 7. Portion of an ambulacrum with the side plates removed. ×20 57

GRANATOCRINUS CAMPANULATUS, *McCoy*, sp., p. 251.

Fig. 8. Summit view of a very young specimen, with a highly ornate calyx and very large prominences at the distal edges of the spiracles. Carboniferous Limestone, Lancashire. ×4 107

Fig. 9. Inferior aspect of another specimen, showing the broad flat base. ×4 . . . 12

Fig. 10. Interradial view of the same individual. ×4 252

GRANATOCRINUS ORBICULARIS, *G. B. Sby.*, sp., p. 248.

Fig. 11. Interradial view, showing the inflated calyx, arched ambulacra, and the position of the radio-deltoid suture. Carboniferous Limestone, Lancashire. ×2 . . 11

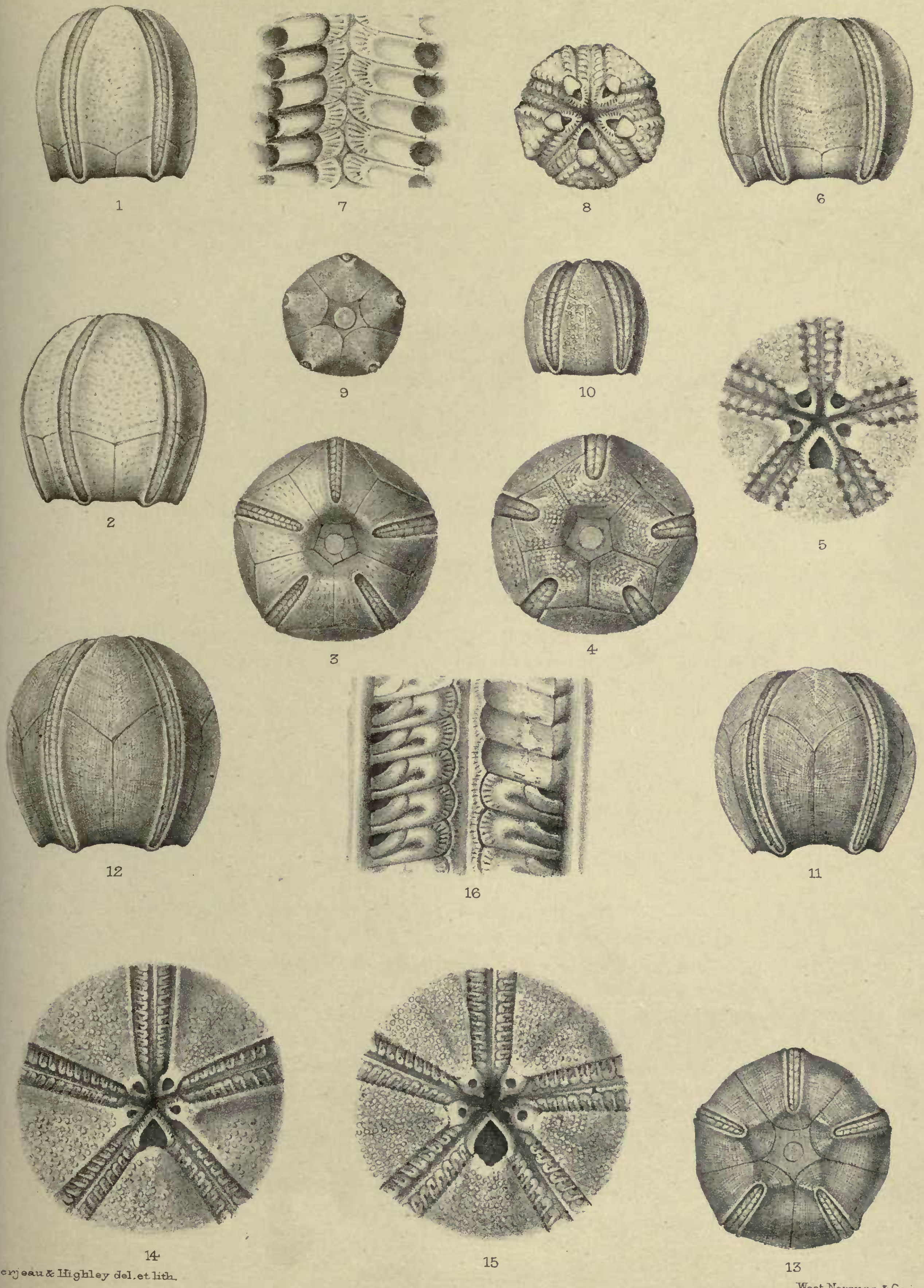
Fig. 12. A similar view of another and higher calyx, with the radio-deltoid suture straighter. ×3 25

Fig. 13. Inferior aspect, showing the converging ambulacra, the wide and shallow central concavity, and the basal disc. ×2 15

Fig. 14. Summit view with the lancet-plate exposed, and the constricted central ends of the deltoids well shown. ×5 107

Fig. 15. A similar view of another example, with the constricted ends of the deltoids larger, and the spiracles somewhat smaller. ×5 107

Fig. 16. Portion of an ambulacrum, showing the median groove of the lancet-plate, and the side plates partially removed on the right. ×20 60



Berjeau & Highley del. et lith.

West, Newman & Co. imp.

Granatocrinus.

PLATE X.

PENTREMITIDEA LUSITANICA, *E. & C.*, p. 173.

Page

Fig. 1. Portion of an ambulacrum, showing the ambulacral groove, the large side plates, and the peculiar outer side plates. Lower Devonian, Asturias. ×12 . . . 62

PENTREMITIDEA SIMILIS, *E. & C.*, p. 180.

Fig. 2. Interradial view, to show the parachute-shaped outline of the calyx. Middle Devonian, Eifel. × 3 170

Fig. 3. Portion of an ambulacrum enlarged, to show the large oblong hydrospire-pores and the peculiar outer side plates. × 12 62

Fig. 4. Summit view of the specimen represented in Fig. 2. × 4 11

GRANATOCRINUS MCCOYI, *E. & C.*, p. 252.

Fig. 5. Interradial view, to show the outline of the calyx, the position of the radio-deltoid suture, and the ornate surface. Carboniferous Limestone, Lancashire. ×5 . 241

Fig. 6. Inferior aspect of the same specimen, exhibiting the broad and almost flat base. × 5 252

Fig. 7. Interradial view of another and rather more inflated individual, with a flatter summit. × 4. 241

Fig. 8. Summit view of the same specimen, showing the lancet-plates with all the side plates removed, and the large partially divided spiracles. × 6 106

GRANATOCRINUS CAMPANULATUS, *McCoy*, sp., p. 251.

Fig. 9. Interradial view of a young specimen, with a very broad and flat base. Carboniferous Limestone, Lancashire. × 5 252

Fig. 10. Summit view of another example, showing the thickened margins of the spiracles. × 5 107

GRANATOCRINUS NORWOODI, *O. & S.*, sp., p. 245.

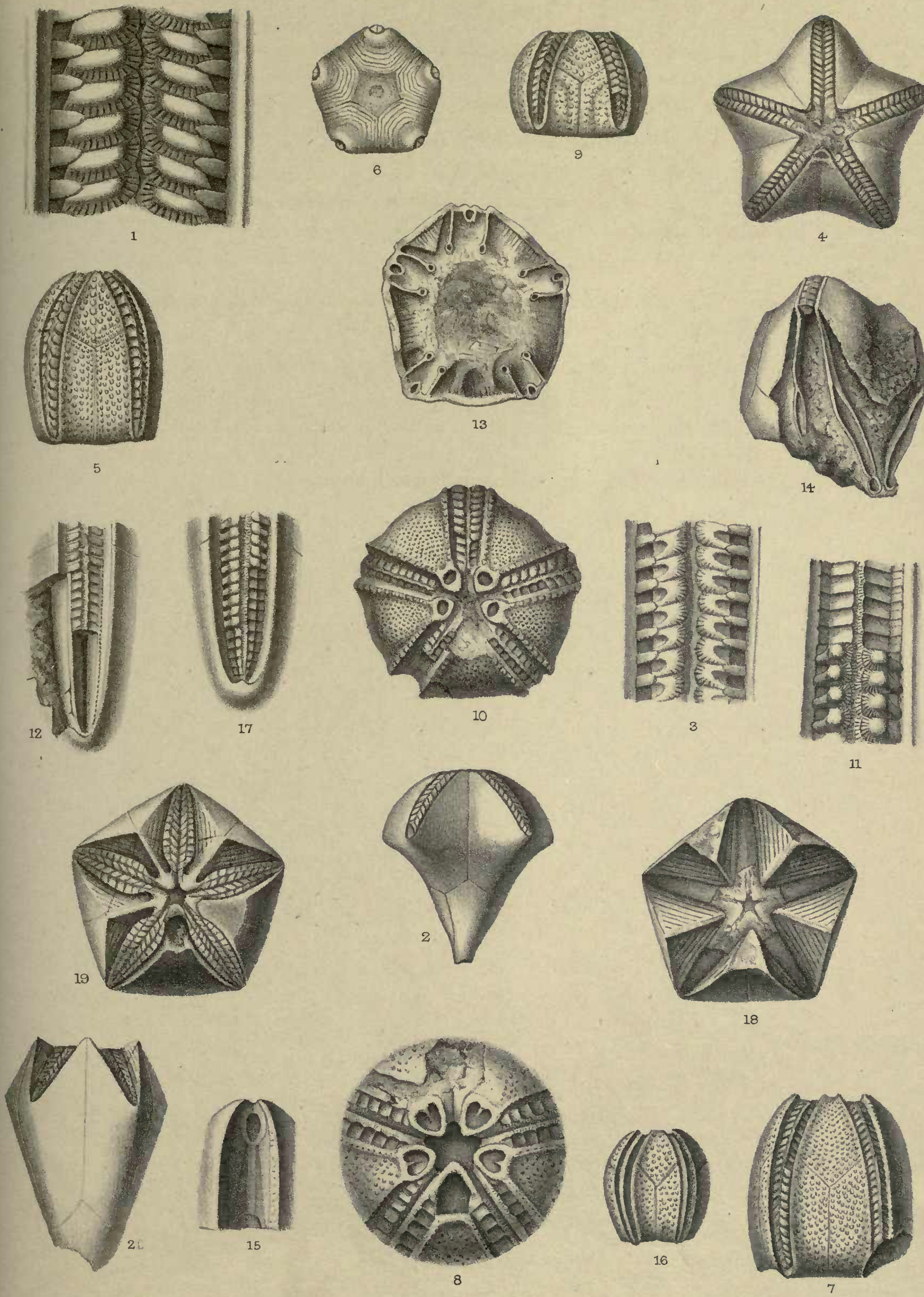
Fig. 11. Portion of an ambulacrum (drawn from two specimens), with the median groove of the lancet-plate exposed in the middle line. The side plates are in position below, but have fallen away above so as to expose the hydrospire-plates. Subcarboniferous, Iowa. *Coll. Wachsmuth.* × 9 58

GRANATOCRINUS ELLIPTICUS, *G. B. Sby.*, sp., p. 253.

Fig. 12. Portion of an ambulacrum, with the lancet-plate and some of the side plates *in situ* above but removed below, so as to show a clear entrance into the visceral cavity of the calyx between the converging hydrospire-plates. On the right side the pores are visible, whilst on the left a portion of the radial plate has been removed to show the hydrospire-plate. Carboniferous Limestone, Lancashire. × 4 . 48

Fig. 13. A very beautiful and naturally weathered cross section of a calyx, which shows the five lancet-canals and the ten hydrospires. × 3 50

Fig. 14. Portion of an inverted and much weathered calyx, showing below two spiracles, and proceeding from them the partially open and partially closed hydrospire-tubes. × 3. 49



Berjeau & Highley del. et lith.

West, Newman & Co. imp.

Pentremitidea. Granatocrinus.
Schizoblastus. Phænoschisma. Codaster.

PLATE XI.

PHÆNOSCHISMA NOBILE, *E. & C.*, p. 275.

Page

Fig. 1. Interradial view of a large specimen, broken below. Lower Devonian, Leon. $\times 1\frac{1}{2}$ 30

Fig. 2. Similar view of the upper part of another specimen, with the outer edges of the sinuses crushed inwards. $\times 1\frac{1}{2}$ 89

Fig. 3. Summit view of the same specimen, showing the wide sinuses, the narrow linear ambulacra, and the radio-deltoid sutures crossing the numerous hydrospire-slits. $\times 1\frac{1}{2}$ 30

Fig. 4. Portion of a radial sinus, to show the narrow ambulacrum and the lancet-plate uncovered at its distal end, and also the arrangement of the hydrospire-slits. $\times 4$ 60

PHÆNOSCHISMA VERNEUILI, *E. & C.*, p. 273.

Fig. 5. Interradial view, to show the high inwardly sloping interradial processes. Lower Devonian, Asturias. $\times 1\frac{1}{2}$ 89

Fig. 6. View of the anal interradius, with less elevated processes, &c. *Coll. P. H. Carpenter.* $\times 2$ 33

PHÆNOSCHISMA ARCHIACI, *E. & C.*, p. 274.

Fig. 7. Section of a calyx from above, showing the thickened plates and the groups of hydrospires. The few hydrospires in the posterior interradius are not seen. (Compare Pl. XIV. fig. 5.) Lower Devonian, Asturias. $\times 6$ 275

OROPHOCRINUS STELLIFORMIS, *O. & S.*, sp., p. 287.

Fig. 8. A radial sinus with the ambulacrum partly preserved. The lancet-plate is exposed in the middle line; on the left is visible the deeper portion of the hydrospire-cleft, whilst on the right there are more of the side plates in position, so as to form the outer opening of the hydrospire-cleft or spiracle. Subcarboniferous, Iowa. *Coll. Wachsmuth.* $\times 4$ 99

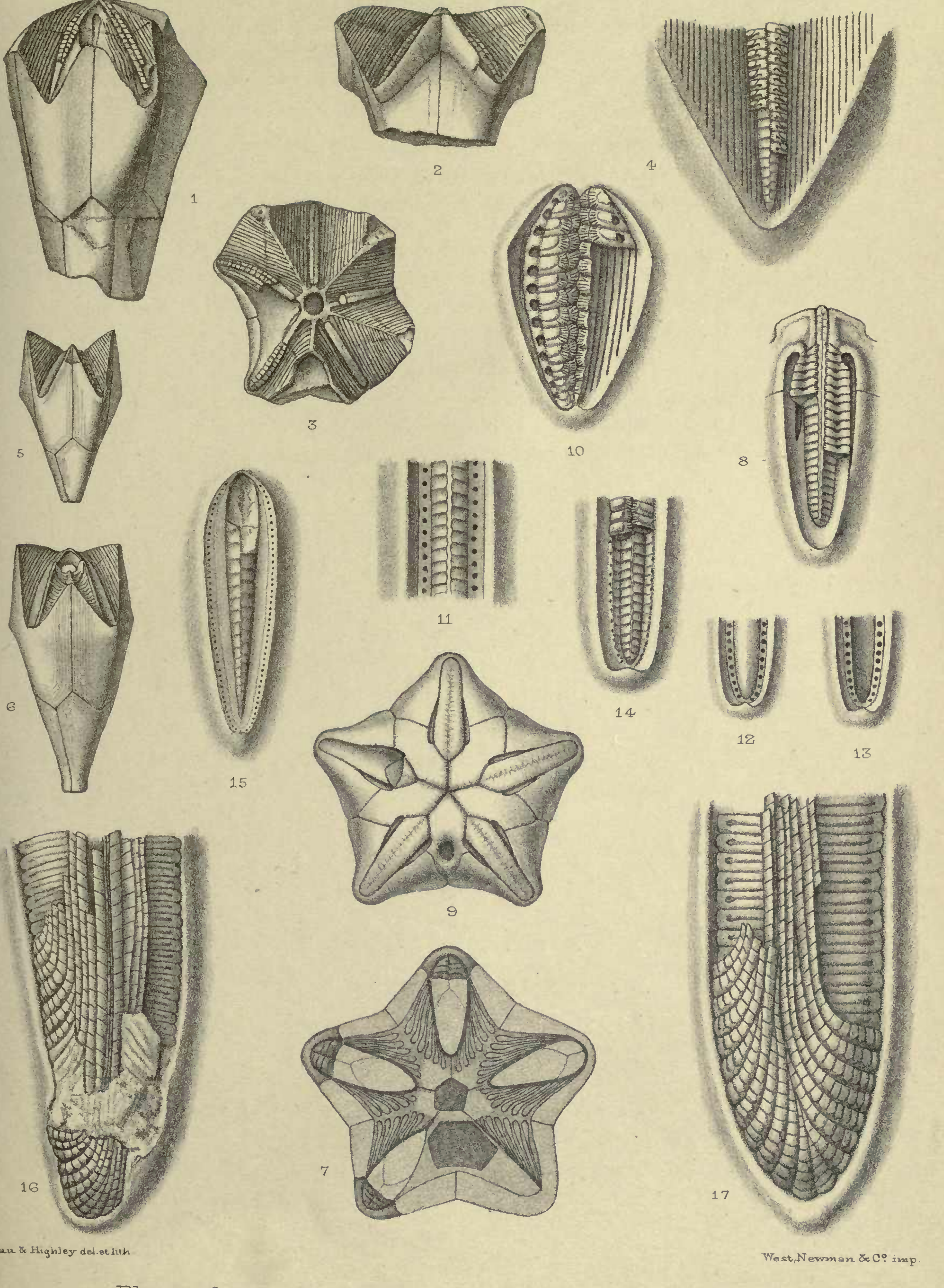
Fig. 9. Summit view of a variety of this species. Subcarboniferous, Iowa. *Coll. Wachsmuth.* $\times 3$ 99

OROPHOCRINUS ORBIGNYANUS, *de Kon.*, sp.

Fig. 10. A radial sinus, with a portion of the ambulacrum *in situ*. In the middle line the lancet-plate is exposed; on the right the side plates are partially removed and the hydrospire-clefts visible; on the left the side plates are in place, and the large pinnule-sockets are well seen. Carboniferous Limestone, Belgium. *Coll. University of Liége.* $\times 10$ 90

GRANATOCRINUS DERBIENSIS, *G. B. Sby.*, sp., p. 250.

Fig. 11. Portion of a radial sinus with the lancet-plate *in situ*, but denuded of the side plates. The hydrospire-pores are visible at its sides. Carboniferous Limestone, Lancashire. $\times 6$ 92



Berjeau & Highley del. et lith.

West, Newman & Co. imp.

Phænoschisma. Granatocrinus. Orophocrinus. Pentremites.

PLATE XII.

Codaster pyramidatus, *Shumard*, p. 266.

		Page
Fig. 1.	Summit view of a moderately well preserved specimen, showing the interradial ridges, ambulacra, hydrospire-slits, mouth, and anus. Corniferous Limestone, Kentucky. × 4	88
Fig. 2.	Radial view of the same specimen. × 3	30
Fig. 3.	Anal interradius of the same. × 3	16

N.B.—The radio-deltoid sutures are rather too distinct, both in these and in the next figure.

Codaster Hindei, *E. & C.*

Fig. 4.	Summit view, showing the same characters as Fig. 1. Hamilton Group, Ontario. *Coll. Hinde.* × 6	32
Fig. 5.	Radial view of the same specimen. × 4	30
Fig. 6.	Anal interradius of the same. × 4	264
Fig. 7.	Portion of an ambulacrum, somewhat worn. × 30	61

Codaster trilobatus, *McCoy*, p. 268.

Fig. 8.	Section of the calyx from above, showing the eight groups of hydrospires and their absence from the anal interradius. Carboniferous Limestone, Lancashire. × 4	32

Orophocrinus verus, *Cumberland*, sp., p. 290.

Fig. 9.	Section of the calyx from above, showing the deep spiracular clefts and the canals within the lancet-plates, one of which is continued onwards to the peristome between two deltoid plates. Carboniferous Limestone, Lancashire. × 6	97

Phænoschisma Archiaci, *E. & C.*, p. 274.

Fig. 10.	Interradial view of a specimen which has the top stem-joint preserved, and a curved interbasal suture. Lower Devonian, Asturias. × 2.	20

Troostocrinus Reinwardti, *Troost*, sp., p. 194.

Fig. 11.	Radial view of the calyx. Niagara Group, Tennessee. × 2	36
Fig. 12.	Terminal portion of a radial sinus, exhibiting the side plates above, underneath them the lancet-plate, and below the latter the tops of the hydrospires. × 4.	93

Pentremites pyriformis, *Say*, p. 167.

Fig. 13.	The proximal end of a radial sinus, showing in the middle line the under lancet-plate, on each side the tops of the hydrospires, and above it the ambulacral opening between two deltoids. Subcarboniferous. *Coll. Hinde.* × 6	51
Fig. 14.	Inner view of the portion of the lancet-plate which fits into the sinus shown in Fig. 13. On the left, at the bottom are visible the backs of five side plates. × 6	34
Fig. 15.	Section of the calyx from above. The water-vascular ring is seen in the centre, with its five branches into the lancet-plates, and between the latter the groups of hydrospires. *Coll. Hinde.* × 5	101

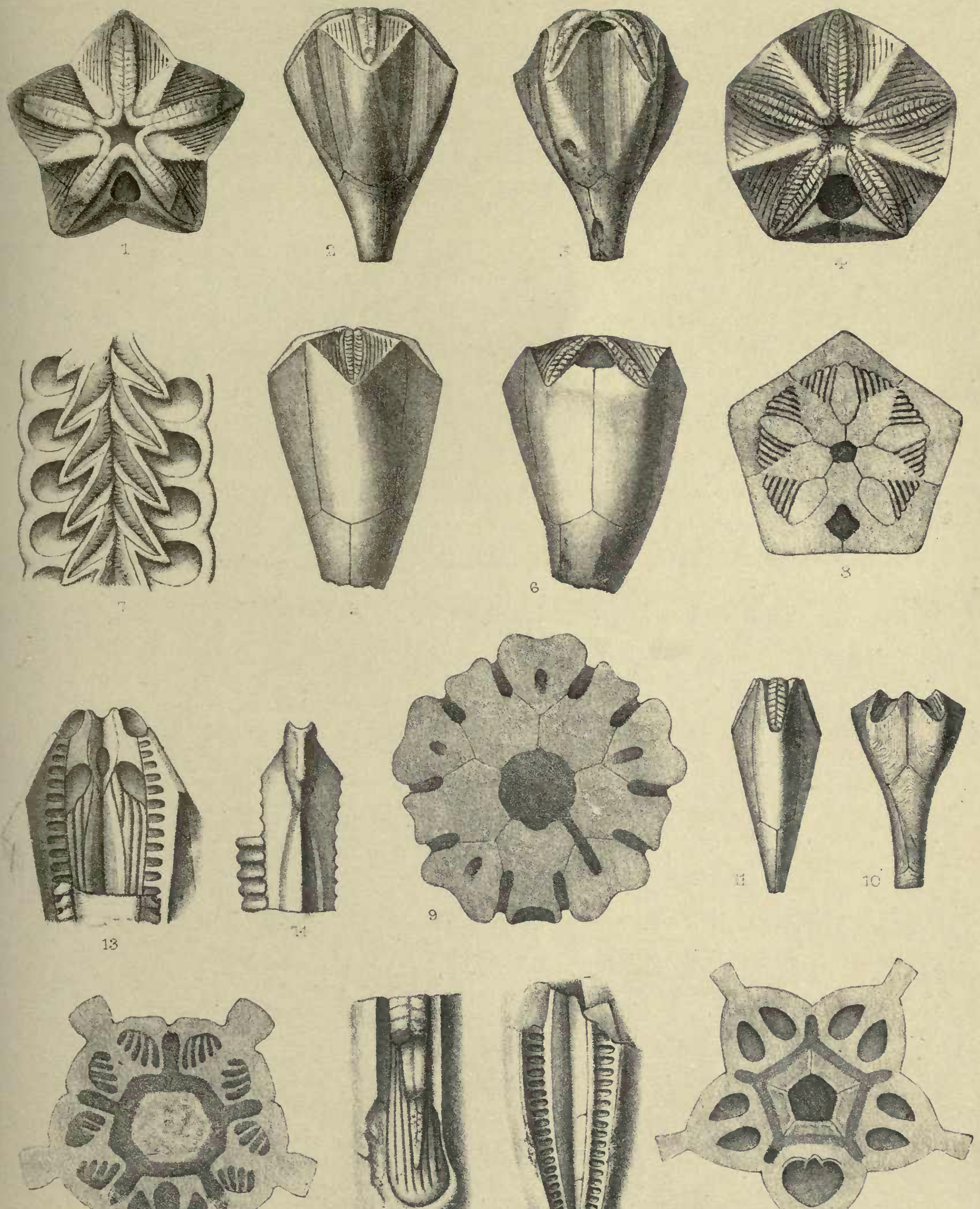
Pentremites Burlingtonensis, *Meek & Worthen.*

Page

Fig. 16. The distal end of a radial sinus as seen after removal of the lancet-plate and side plates, so as to expose the under lancet-plate which completely conceals the hydrospires. Subcarboniferous, Iowa. *Coll. Wachsmuth.* ×3 4

Pentremites Godoni, *Defrance*, sp., p. 157.

Fig. 17. Section of the calyx from above, showing the water-vascular ring and its extensions into the lancet-canals. The spiracular canals leading to the hydrospires are also shown. Subcarboniferous, Alabama. ×6 101



Berjeau & Highley del. et lith.

West, Newman & Co. imp.

Codaster. Orophocrinus.
Phænoschisma. Troostocrinus. Pentremites.

PLATE XIII.

[illegible], McCoy, p. [illegible].

Fig. 1. Summit view of a very perfect specimen, showing the prominent interradial ridges, [illegible] sutures, [illegible], and seven hydrospire-slits on each side of an ambulacrum. Carboniferous Limestone, Lancashire and Yorkshire. × 3.

Fig. 2. Interior aspect of the same specimen, showing the basal plates and the [illegible] cup. × 4. 11

Fig. 3. Interradial view of the same showing the basal cup and radial plates. × 3. 29

Fig. 4. Summit view of another specimen, in which there are only four hydrospire-slits visible on each side of an ambulacrum. × [illegible] 14

Fig. 5. Vertical section of a portion of a calyx, with the five rows of the hydrospire [illegible] within the [illegible]. × 3. 33

Fig. 6. A [illegible] in which a radial plate has been removed, exposing [illegible] hydrospires [illegible] side of the [illegible]. × 3. 48

Fig. 7. Portion of a cross-section of the calyx shown in Fig. 6 seen from above, with the eight groups of hydrospires. × 3. 38

Fig. 8. Portion of a summit with [illegible], with two radio-deltoid sutures, and ten hydrospire-slits on each side of the ambulacrum. × 4. 8

[illegible], McCoy, sp., p. 260.

Fig. 9. Interradial view of the [illegible] portion of a calyx. Carboniferous Limestone, Lancashire and Yorkshire. × 3. 33

Fig. 10. Radial view of a complete calyx. × 3. 50

Fig. 11. Interradial view of the upper part of a calyx of a more robust form. × 3. 38

Fig. 12. Radial view of a complete calyx. × 3. [illegible]

Fig. 13. Under view, showing the basal plates and the tripod cup. × 3. 10

Fig. 14. An ambulacrum, showing the larger plate and three side plates in situ on each side. × 8. 56

Fig. 15. Radial view of a large variety, with a more [illegible] base, and some remains of ornament on the plates. × 3. 12

[illegible], Cumb., sp., p. 264.

Fig. 16. Part of an ambulacrum, showing the [illegible] between the side plates. Carboniferous Limestone, Lancashire. × 12. 61

[illegible], sp., p. 269.

Fig. 17. Basal view, with the columnar cavity occupied by the remains of a stem-joint. Carboniferous Limestone, [illegible]. Natural size. 12

Fig. 18. Interradial view, showing the broad ambulacra, and the outline of the tubercles on the radio-deltoid sutures. Natural size. 100

Fig. 19. View of an ambulacrum, with [illegible] of the side plates in position, and below them the lancet-plate [illegible], showing the [illegible]. The pores are also visible. × 14. 95

[illegible], d'Orbigny, sp., p. 281.

Fig. 20. A portion of the [illegible], showing two spiracles [illegible] interradius, with the narrow exposed portion of the [illegible] plate between them. Upper Devonian, [illegible]. × 3. 22

PLATE XIII.

Codaster trilobatus, *McCoy*, p. 268.

Page

Fig. 1. Summit view of a very perfect specimen, showing the ambulacra, interradial ridges, radio-deltoid sutures, mouth, anus, and seven hydrospire slits on each side of an ambulacrum. Carboniferous Limestone, Lancashire and Yorkshire. × 3. 22

Fig. 2. Inferior aspect of the same specimen, showing the basal plates and the trilobate cup. × 2 16

Fig. 3. Interradial view of the same, showing the basal cup and radial plates. × 2 . . 24

Fig. 4. Summit view of another specimen, in which there are only four hydrospire-slits visible on each side of an ambulacrum. × 4 13

Fig. 5. Vertical section of a portion of a calyx, with the free ends of the hydrospires pendent within the visceral cavity. × 2 88

Fig. 6. A naturally weathered calyx, in which a radial plate has been removed, exposing seven hydrospires on each side of the ambulacrum. × 2 88

Fig. 7. Portion of a cross section of the calyx shown in Fig. 5, seen from above, with the eight groups of hydrospires. × 2 88

Fig. 8. Portion of a summit, seen obliquely, with two radio-deltoid sutures, and ten hydrospire-slits on each side of the ambulacrum. × 3 8

Codaster trilobatus, *var.* acutus, *McCoy*, var., p. 269.

Fig. 9. Interradial view of the upper portion of a calyx. Carboniferous Limestone, Lancashire and Yorkshire. × 4 23

Fig. 10. Radial view of a complete calyx. × 3 16

Fig. 11. Interradial view of the upper part of a calyx of a more robust form. × 4 . . 23

Fig. 12. Radial view of a complete calyx. × 3 24

Fig. 13. Under view, showing the basal plates and the tripod cup. × 3 16

Fig. 14. An ambulacrum, showing the lancet-plate and three side plates *in situ* on each side. × 8. 55

Fig. 15. Radial view of a large variety, with a more pointed base, and some remains of ornament on the plates. × 3 16

Orophocrinus verus, *Cumb.* sp., p. 290.

Fig. 16. Part of an ambulacrum, showing the large sockets between the side plates. Carboniferous Limestone, Lancashire. × 12 61

Acentrotremites ellipticus, *Cumb.*, sp., p. 235.

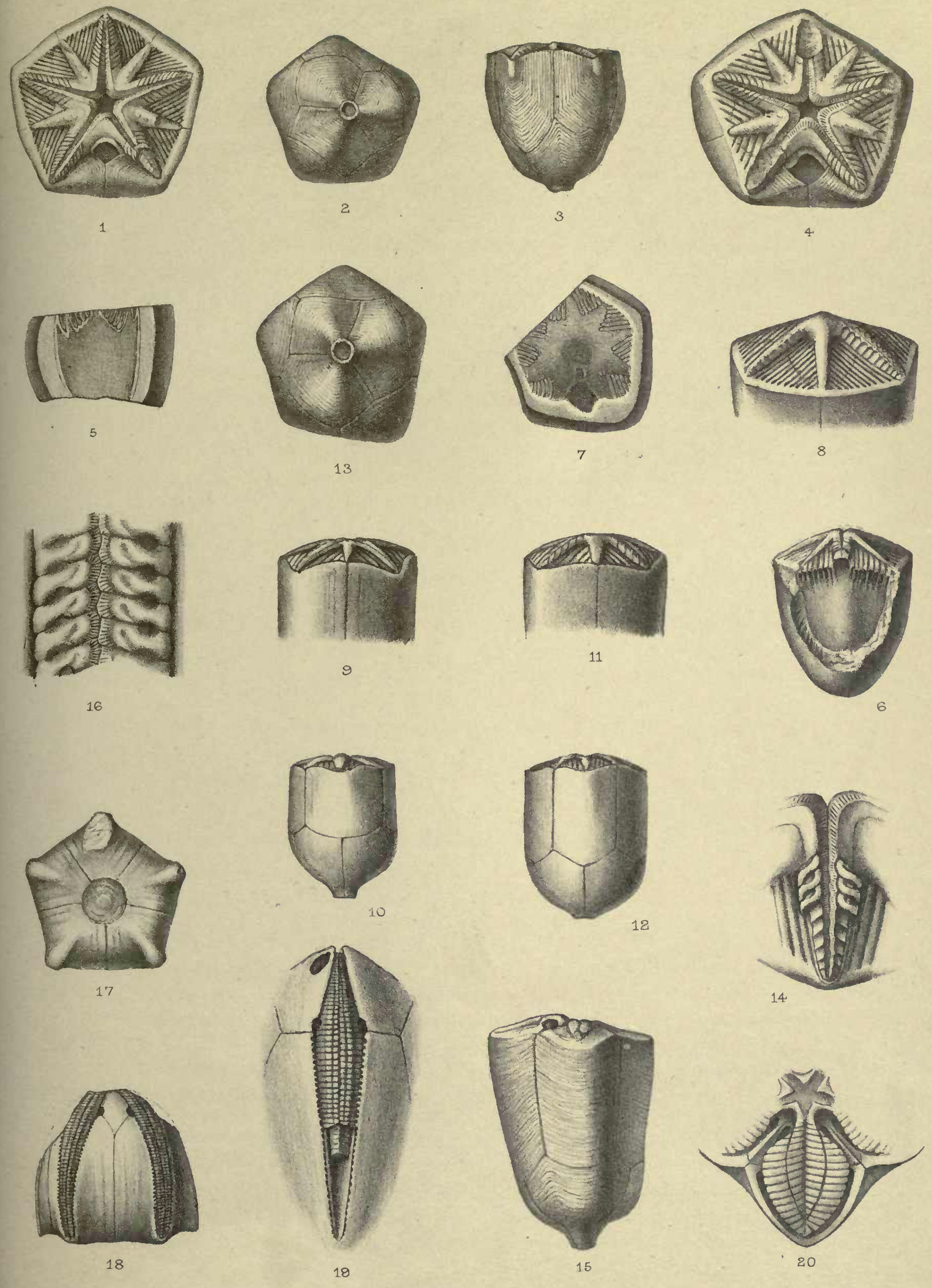
Fig. 17. Basal view, with the columnar cavity occupied by the remains of a stem-joint. Carboniferous Limestone, Somersetshire. Natural size 12

Fig. 18. Interradial view, showing the broad ambulacra, and the position of the spiracles on the radio-deltoid sutures. Natural size 108

Fig. 19. View of an ambulacrum, with most of the side plates in position, and below them the lancet-plate broken short-off; the spiracles and the anus are also visible. × $1\frac{1}{2}$ 93

Cryptoschisma Schulzi, *d'Archiac & de Vern.*, sp., p. 281.

Fig. 20. A portion of the summit, showing two spiracles in each interradius, with the narrow exposed portions of the deltoid plates between them. Lower Devonian, Asturias. × 6 97



Bergeron & Highley del. et lith. West, Newman & C°

Codaster. Orophocrinus. Acentrotremites. Cryptoschisma.

PLATE XIV.

PHÆNOSCHISMA CARYOPHYLLATUM, *de Kon.*, sp., p. 277.

		Page
Fig. 1.	Interradial view of a specimen with the ambulacra removed, exhibiting the form of the radial and basal plates, and the position of the hydrospire-slits. Carboniferous Limestone, Belgium. ×3	16
Fig. 2.	A radial sinus with the side plates removed from the lancet-plate, exposing the hydrospires on each side. ×4	93
Fig. 3.	A radial sinus with the lancet-plate and side plates *in situ*. The distal extremities of the hydrospire-slits are visible at the sides of the ambulacrum. ×4	57
Fig. 4.	An interradial view of a complete calyx. ×4	89

PHÆNOSCHISMA ARCHIACI, *E. & C.*, p. 274.

Fig. 5.	Summit view of a specimen which has lost nearly all its side plates, so that the hydrospire-slits are fully visible. Lower Devonian, Asturias. ×4	89
Fig. 6.	A radial sinus with the ends of the lancet-plates visible above and below, and its middle portion covered by the side plates; one or two hydrospire-slits are visible at their sides. ×8	62
Fig. 7.	A radial sinus, with the lancet-plate exposed by the removal of the side plates. Six hydrospire-slits are visible on each side. ×8	89

PHÆNOSCHISMA VERNEUILI, *E. & C.*, p. 273.

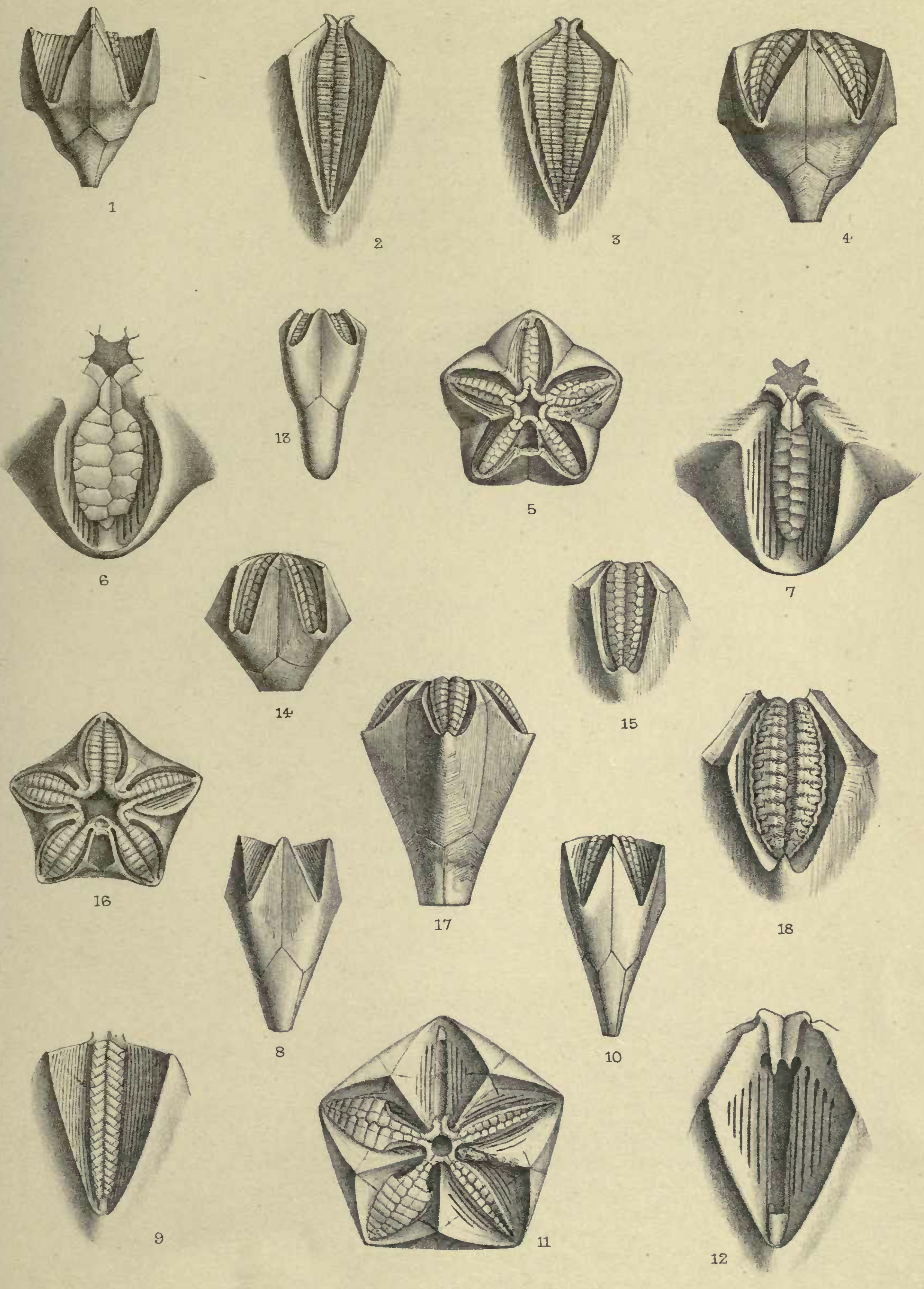
Fig. 8.	Interradial view showing the interradial processes, hydrospire-slits, and some remains of the ornament. Lower Devonian, Asturias. ×2	24
Fig. 9.	A radial sinus with the narrow ambulacrum intact, and the radio-deltoid sutures crossing the hydrospire-slits on the sides of the sinus. ×4	62

PHÆNOSCHISMA ACUTUM, *G. B. Sby.*, sp., p. 276.

Fig. 10.	Interradial view, showing the exposed lancet-plates of two ambulacra, and the hydrospire-slits at their sides. Carboniferous Limestone, Lancashire. ×3	24
Fig. 11.	Summit view of the same specimen. Two of the ambulacra are almost intact, but in two other sinuses only the lancet-plates remain, and in the fifth the whole of the ambulacral plates have been removed. ×6	89
Fig. 12.	A radial sinus as exposed by the removal of all the ambulacral structures except the tip of the lancet-plate. The visceral cavity is visible in the median line and the hydrospire-slits on its sides. ×8	44

PENTREMITIDEA PAILLETTEI, *de Verneuil*, sp., p. 172.

Fig. 13.	Interradial view, showing the general features of the calyx. Lower Devonian, Asturias. ×2	24



Berjeau & Highley del et lith.

West, Newman & Co. imp.

Pentremitidea. Phænoschisma. Orophocrinus.

PLATE XL.

[illegible] Carboniferous, p. [illegible].

Page

Fig. 1. Basal view of [illegible]. Carboniferous Limestone, Derbyshire. $\times 3$. . . . 11

Fig. 2. [illegible] view of [illegible] specimen, with the [illegible] well shown. $\times 1\frac{1}{2}$ 92

Fig. 3. [illegible] of a [illegible], showing the position of the [illegible]. Natural size 201

Fig. 4. A radial plate, with the [illegible] plate and the other [illegible] plates removed, so as to expose the [illegible], the [illegible] openings, the hydrospires [illegible], and the tops of the hydrospires seen through them. $\times 4$ 41

[illegible], p. [illegible].

Fig. 5. [illegible] view of a specimen in which the [illegible] plates are visible, and also the [illegible] with the upper lancet-plate [illegible]. Carboniferous Limestone, Derbyshire. $\times 1\frac{1}{2}$ 90

Fig. 6. [illegible] view of the same specimen, which is broken at the base. $\times 1\frac{1}{2}$ . . . 18

Fig. 7. Section of an ambulacrum, with the [illegible] lancet-plate [illegible] the middle line, and large deep [illegible] between the side plates. $\times 12$ . . . 41

[illegible], var. [illegible], p. 208.

Fig. 8. [illegible] view of a [illegible] individual, with the [illegible] removed from two of the [illegible]. Carboniferous Limestone, Belgium. $\times 1\frac{1}{2}$ 90

Fig. 9. Radial view of the same specimen, with an additional [illegible], narrow basal plate. Natural size 18

Fig. 10. A radial plate with the [illegible] removed [illegible] large [illegible] plate, which is partially [illegible] from the [illegible] cavity. The tops of the [illegible] are [illegible] of the [illegible] surface. $\times$ [illegible] . . . 47

[illegible], p. 267.

Fig. 11. The [illegible] of a well-preserved specimen with a [illegible], [illegible] and [illegible], and [illegible]. [illegible], Iowa. Coll. Wachsmuth 92

Fig. 12. Enlarged view of the [illegible] and [illegible] over the ambulacra. $\times$ [illegible] 68

Fig. 13. A [illegible] of the specimen figured on Pl. XL, with the [illegible] broken near the [illegible], [illegible] under [illegible] plate, [illegible] . $\times$ [illegible] 47

Fig. 14. [illegible] of an ambulacrum, showing the [illegible] of the lancet-plate in the middle line, [illegible] and the [illegible] the [illegible] of the [illegible]. $\times$ [illegible] 91

Fig. 15. The [illegible] of a [illegible] the hydrospires [illegible] at the sides of [illegible]. $\times$ [illegible] 91

PLATE XV.

Orophocrinus verus, *Cumb.*, sp., p. 290.

Page

Fig. 1. Radial view of a typical example. Carboniferous Limestone, Lancashire. ×2. 11

Fig. 2. Summit view of another specimen, with the long hydrospire-clefts well shown. ×$1\frac{1}{2}$ 97

Fig. 3. Anal interradius of a more inflated variety, showing the position of the anal deltoid. Natural size 291

Fig. 4. A radial sinus, with the lancet-plate and the other ambulacral plates removed, so as to expose the under lancet-plate, the ambulacral opening, the hydrospire-clefts, and the tops of the hydrospires seen through them. ×4 47

Orophocrinus pentangularis, *Miller*, sp., p. 292.

Fig. 5. Summit view of a specimen in which the deltoid plates are visible, and also one ambulacrum with the under lancet-plate exposed. Carboniferous Limestone, Lancashire. ×$1\frac{1}{2}$ 90

Fig. 6. Interradial view of the same specimen, which is broken at the base. ×$1\frac{1}{2}$. . . 11

Fig. 7. Portion of an ambulacrum, with the grooved lancet-plate exposed in the middle line, and large deep pinnule-sockets between the side plates. ×12 . 61

O. pentangularis, *Miller*, var. Waterhousianus, *de Kon.*, var., p. 293.

Fig. 8. Summit view of a rather malformed individual, with the lancet-plates removed from two of the sinuses. Carboniferous Limestone, Belgium. ×$1\frac{1}{2}$ . . . 90

Fig. 9. Radial view of the same specimen, with an additional interpolated, narrow basal plate. Natural size 11

Fig. 10. A radial sinus with the ambulacral structures removed so as to expose the under lancet-plate, which is partially broken away, thus laying open the visceral cavity. The tops of the hydrospire-folds are visible in the spiracular clefts. ×3. . 47

Orophocrinus stelliformis, *O. & S.*, sp., p. 287.

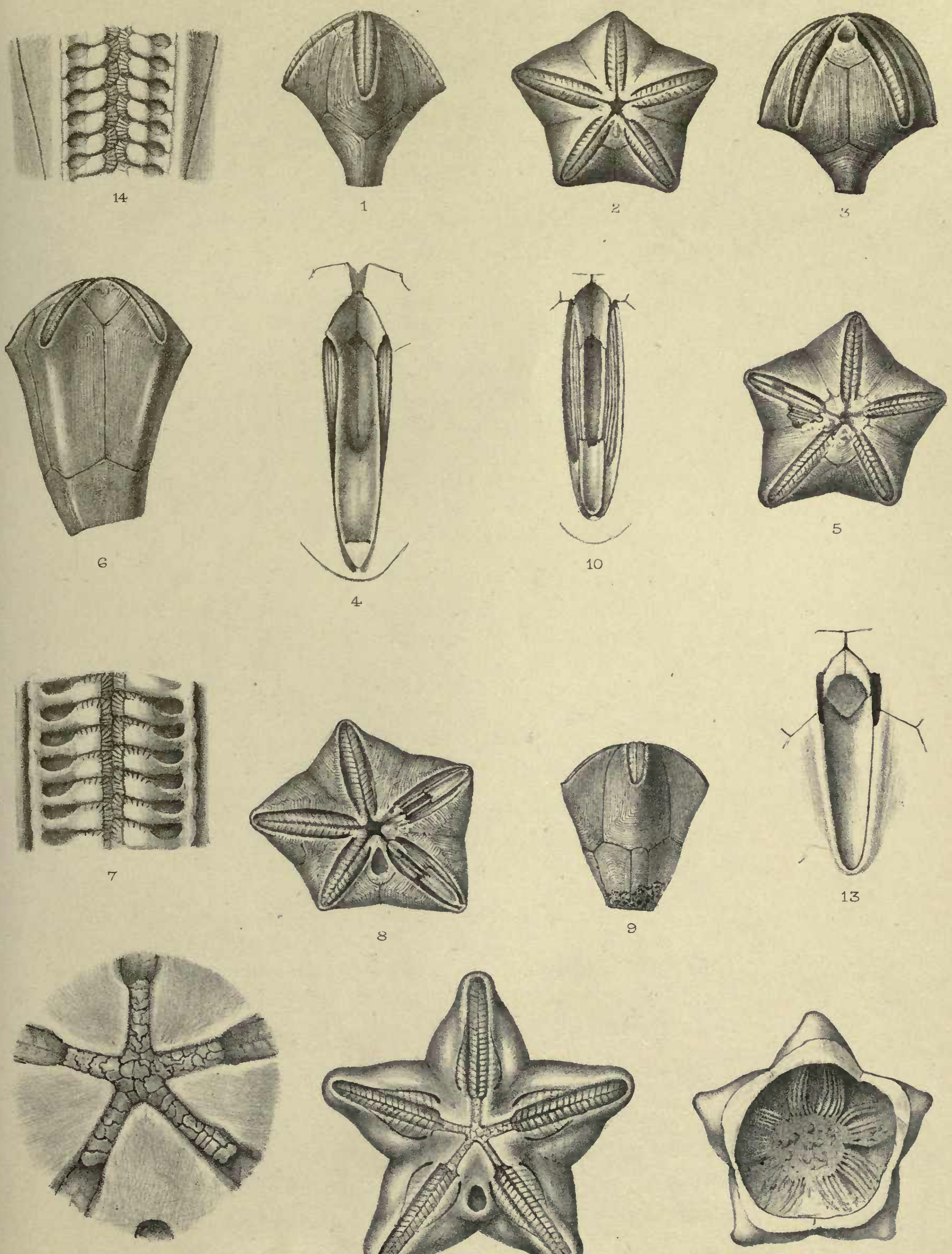
Fig. 11. The ventral aspect of a well-preserved specimen with a closed peristome, curved and elongated spiracles, and subpetaloid ambulacra. Subcarboniferous, Iowa. *Coll. Wachsmuth.* × 99

Fig. 12. Enlarged view of the central summit-plates and their extensions over the ambulacra. ×8. 68

Fig. 13. A dissected ambulacrum of the specimen figured on Pl. XI. with the lancet-plate broken near its proximal end, a well-defined under lancet-plate, and very short spiracles. ×4 47

Fig. 14. Portion of an ambulacrum, showing the groove of the lancet-plate in the middle line, and the oval sockets between the side plates, some of them filled in with calcite, the others empty. The lines at the sides are the distal ends of the spiracles. *Coll. Wachsmuth.* ×10 61

Fig. 15. The interior of a calyx seen from below, with the hydrospires visible at the sides of the ambulacra. *Coll. Wachsmuth.* ×2 91



Berjeau & Highley del et lith.

West, Newman & Co imp.

Orophocrinus

PLATE XVI.

Codaster gracilis, *Wachsmuth*, sp.

Page

Fig. 1. View of a radial sinus with the radio-deltoid sutures descending its walls and crossing the hydrospire-slits. Upper Devonian, Michigan. *Coll. P. H. Carpenter.* ×6 33

Codaster trilobatus, var. acutus, *McCoy*, var., p. 269.

Fig. 2. Radial view of a sinus showing the radio-deltoid sutures, and three hydrospire-slits on each side. Carboniferous Limestone, Lancashire and Yorkshire. ×6. . 33

Cryptoschisma Schulzi, *d'Arch. & de Vern.*, sp., p. 281.

Fig. 3. Internal view of a radial plate, showing the distal ends of the hydrospires. Lower Devonian, Leon. *Coll. P. H. Carpenter.* ×4 90

Fig. 4. Sectional view of a fractured ambulacrum, showing the side plates resting over the upper ends of the hydrospires. Lower Devonian, Leon. *Coll. P. H. Carpenter.* ×4. 9

Orophocrinus stelliformis, *O. & S.*, sp., var. campanulatus, *Hambach*, var., p. 289.

Fig. 5. Radial view of an example with a constricted basal cup. Subcarboniferous, Illinois. ×2 20

Orophocrinus stelliformis, *O. & S.*, sp., p. 288.

Fig. 6. Interior aspect of a radial plate exhibiting the distal ends of the hydrospires. Subcarboniferous, Illinois. *Coll. Wachsmuth.* ×2 91

Fig. 7. Radial view of a specimen in which the anchylosed top stem-joints are well seen. Subcarboniferous, Illinois. *Coll. Wachsmuth.* ×1½ 19

Orophocrinus pentangularis, *Miller*, sp., var. Waterhousianus, *de Kon.*, var., p. 293.

Fig. 8. Anal interradius. Carboniferous Limestone, Belgium. Natural size 16

Fig. 9. Base of the same, showing an interpolation of additional plates arising from repair to an injury. Natural size 293

Orophocrinus verus, *Cumberland*, sp., p. 290.

Fig. 10. An almost complete anal aperture. Carboniferous Limestone, Lancashire. ×4 286

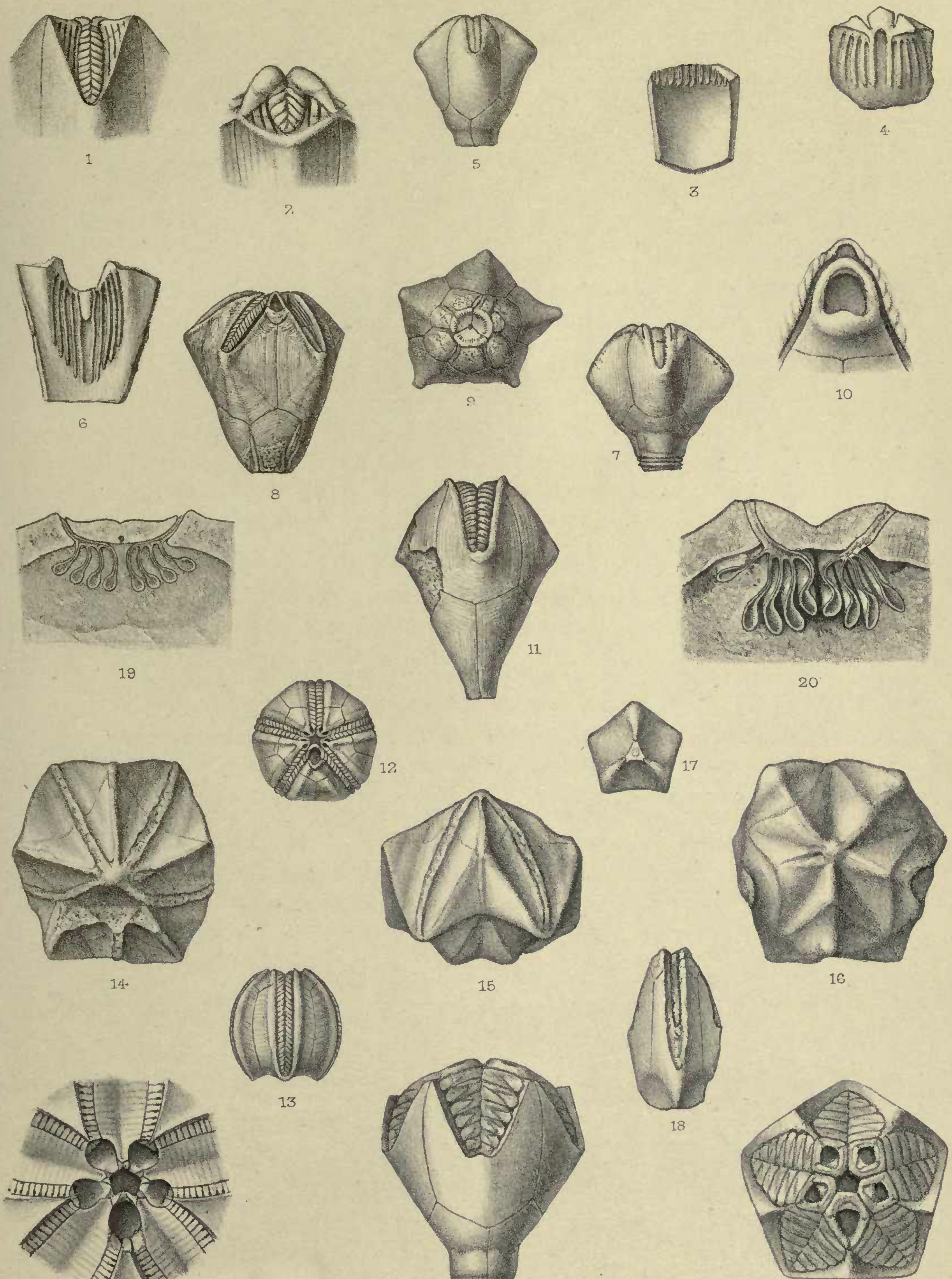
Pentremitidea Roemeri, *E. & C.*

Fig. 11. Radial view of an almost complete specimen. Middle Devonian, Eifel. *Coll. F. Roemer.* ×4 175

Schizoblastus Bailii, *E. & C.*

Fig. 12. Summit view, showing the double spiracles. Carboniferous Limestone, Ireland. *Coll. Geological Survey of Ireland.* ×2. 111

Fig. 13. Radial view of the same specimen. ×2 221



Berjeau & Highley del. et lith.

West, Newman & Co. imp.

Pentremites. Orophocrinus. Pentephyllum.
Cryptoschisma. Codaster. Pentremitidea. Schizoblastus.
Troostocrinus.

PLATE XVII.

SCHIZOBLASTUS SAYI, *Shumard,* sp., p. 224.

Page

Fig. 1. Cross section of an ambulacral field and the hydrospires attached, five tubes on each side; the lancet-plate is trebly perforated. Subcarboniferous, Iowa. *Coll. Wachsmuth.* ×4 54

SCHIZOBLASTUS ROFEI, *E. & C.,* p. 228.

Fig. 2. A similar section, one hydrospire-tube on each side. Carboniferous Limestone, Wexford. ×10 92

GRANATOCRINUS CAMPANULATUS, *McCoy,* sp., p. 251.

Fig. 3. A similar section, one hydrospire-tube on each side. Carboniferous Limestone, Lancashire. ×15 92

GRANATOCRINUS DERBIENSIS, *G. B. Sby.,* sp., p. 250.

Fig. 4. A similar section, one hydrospire-tube on each side, the lancet-plate perforated by a single canal, and one side plate remaining in place. Carboniferous Limestone, Lancashire. ×10 46

GRANATOCRINUS ORBICULARIS, *G. B. Sby.,* sp., p. 248.

Fig. 5. A similar section to Fig. 3. Carboniferous Limestone, Lancashire. × . . . 92

GRANATOCRINUS ELLIPTICUS, *G. B. Sby.,* sp., p. 253.

Fig. 6. A similar section, with the sacs of the hydrospires large and pyriform, and the lancet-canal visible. Carboniferous Limestone, Lancashire. ×8 46

Fig. 7. A similar section of a wide ambulacrum, one hydrospire-sac on each side, and the lancet-canal visible. Carboniferous Limestone, Lancashire. ×14 . . 92

GRANATOCRINUS NORWOODI, *O. & S.,* sp., p. 245.

Fig. 8. A similar section, showing the side plates in position, the lancet-canal, and the hydrospire-canals seeming to perforate the radial plates. Subcarboniferous, Iowa. ×12 46

MESOBLASTUS ANGULATUS, *G. B. Sby.,* sp., p. 185.

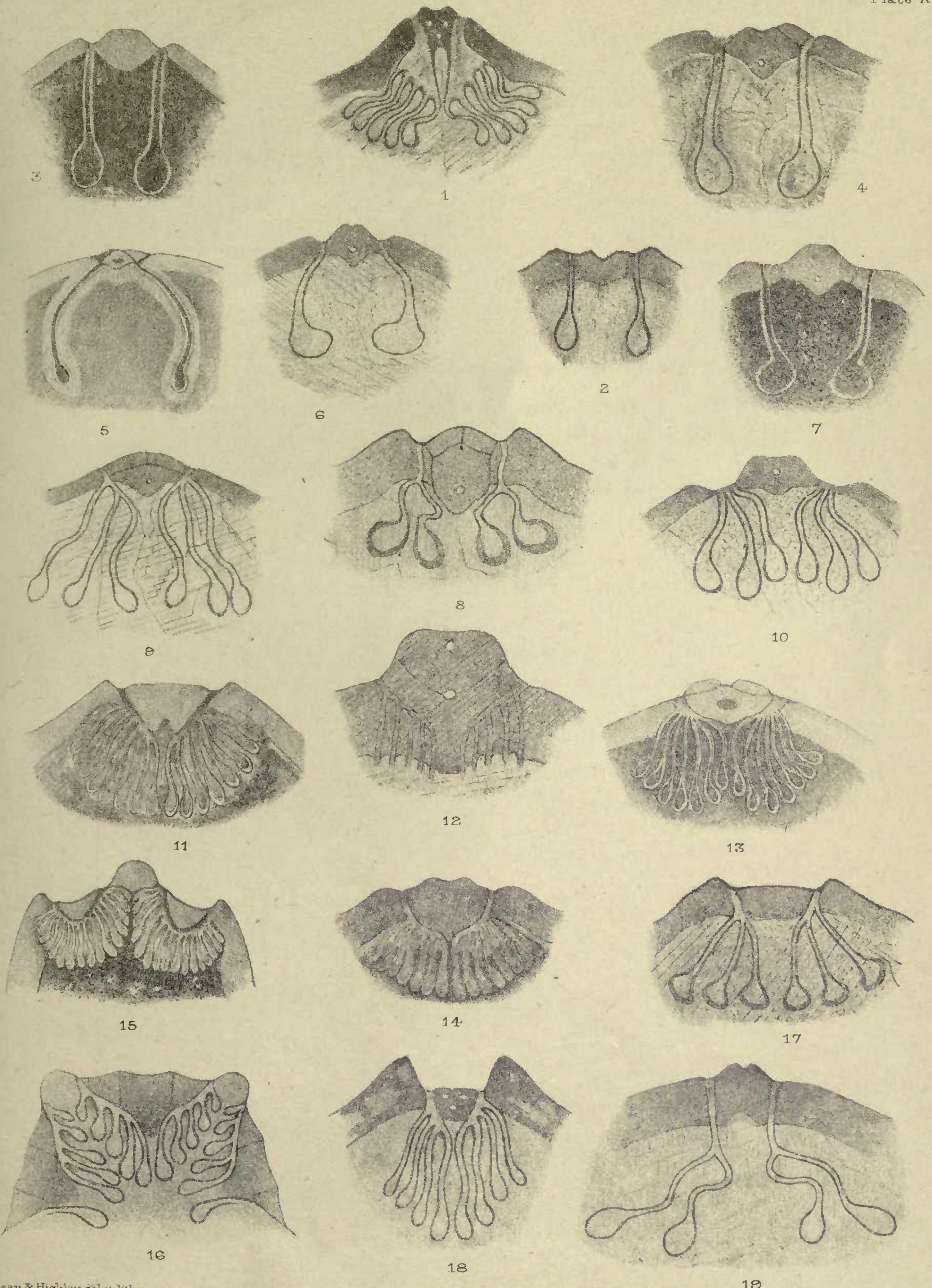
Fig. 9. A similar section, the side plates in position, the lancet-canal visible, and three hydrospire-tubes on each side. Carboniferous Limestone, Lancashire. ×6 46

MESOBLASTUS ELONGATUS, *G. B. Sby.,* sp., p. 186.

Fig. 10. A similar section, with the lancet-canal visible and three hydrospire-tubes on each side. Carboniferous Limestone, Lancashire. ×8 92

PENTREMITIDEA PAILLETTEI, *de Verneuil,* sp., p. 172.

Fig. 11. A similar section. Eight hydrospire-tubes are present on each side, the uppermost ones almost piercing the substance of the radials; and the lancet-plate is grooved beneath. Lower Devonian, Asturias. ×6 49



Berjeau & Highley del.et lith.

West, Newman & C° imp.

Schizoblastus. Granatocrinus. Pentremitidea.
Orophocrinus. Phaenoschisma. Troostocrinus. Elæacrinus.

PLATE XVIII.

CODASTER TRILOBATUS, var. ACUTUS, *McCoy*, var., p. 269.

Page

Fig. 1. Cross section of an ambulacrum, with the side plates in position, the lancet-canal visible, and five hydrospire-tubes on each side. Carboniferous Limestone, Lancashire. ×10 88

CRYPTOSCHISMA SCHULZI, *d'Archiac & de Vern.*, sp., p. 281.

Fig. 2. A similar section, with eight hydrospire-tubes on each side. Lower Devonian, Asturias. ×9 90

PENTREMITES PYRIFORMIS, *Say*, p. 167.

Fig. 3. A similar section, with the side plates in position and the lancet-canal visible; seven hydrospire-tubes on each side. Subcarboniferous, Illinois. *Coll. Wachsmuth.* ×8 48

PENTREMITES ELONGATUS, *Shumard*, p. 161.

Fig. 4. A similar section, three hydrospire-tubes on each side. Subcarboniferous, Iowa. *Coll. Wachsmuth.* ×6 46

PENTREMITES SULCATUS, *Roemer*, sp., p. 165.

Fig. 5. A similar section, the side plates in position, with six hydrospires on one side and four on the other. The concavity of the whole ambulacrum is well shown; another figure of it is given on Pl. XVI. fig. 20. Subcarboniferous, Illinois. ×4 41

PENTREMITES CONOIDEUS, *Hall*, p. 162.

Fig. 6. A similar section, four hydrospire-tubes visible on each side. Subcarboniferous, Indiana. ×4 46

Fig. 7. Internal aspect of a radial plate with one of the limbs broken. Subcarboniferous, Indiana. *Coll. J. G. Hinde.* ×2 95

Fig. 8. Exterior of the same plate, after removal of the ambulacral plates and hydrospires, which last are cut off from the body-cavity by the ingrowth of the sides of the sinus. ×2 95

OROPHOCRINUS GRACILIS, *M. & W.*, sp.

Fig. 9. Summit view (after Meek and Worthen), showing the spiracular clefts. Subcarboniferous, Iowa. ×? 98

TRICŒLOCRINUS OBLIQUATUS, *Roemer*, sp., p. 206.

Fig. 10. External aspect of a broken radial plate, with the sinus and ambulacrum extending three fourths the length of the plate. Subcarboniferous, Indiana. Natural size. 95

Fig. 11. Interior of the same, with no appearance of a sinus excavating the plate, and the hydrospires situated in the substance of the plate at its upper end. Natural size. 95

Fig. 12. External aspect of another radial. Natural size 95

Page

Fig. 13. Cross section of the same at its upper end, showing the ambulacrum in the narrow sinus, and the hydrospires buried in the substance of the plate. Natural size. 95

Fig. 14. Cross section of a radial plate with the hydrospires imbedded in its substance. Probably of a different species. Subcarboniferous, Indiana. *Coll. Wachsmuth.* ×3. 95

METABLASTUS WACHSMUTHI, *Gurley*, sp.

Fig. 15. Summit view of a much decorticated example, showing the positions of the anus and of the double spiracles, &c. Subcarboniferous, Indiana. *Coll. Wachsmuth.* ×3. 110

ELÆACRINUS VERNEUILI, *Troost*, sp., p. 216.

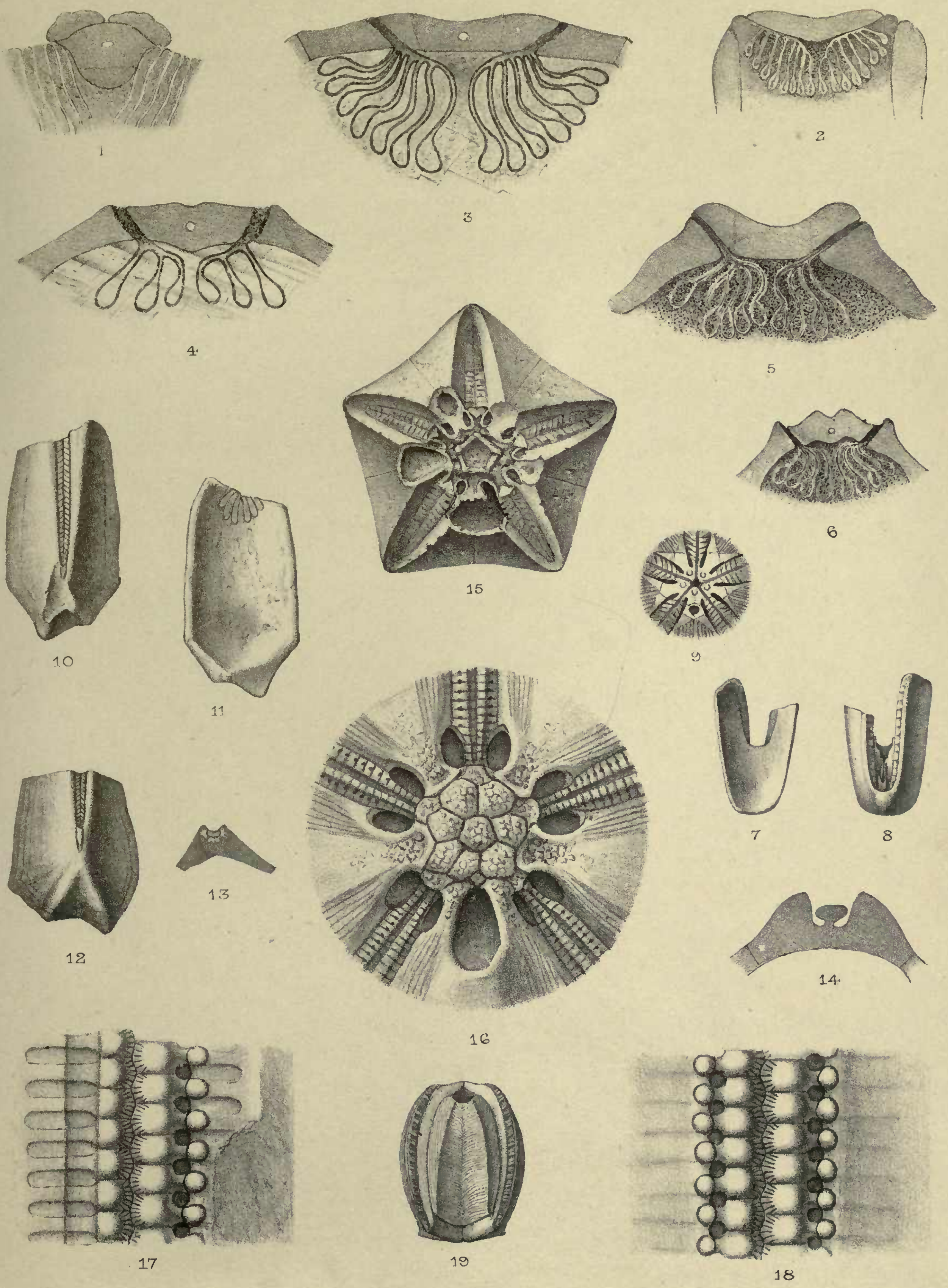
Fig. 16. Summit view, showing the position of the anus, the double spiracles, and the central vault-plates covering the peristome. Corniferous Limestone, Kentucky. ×4. 74

Fig. 17. Portion of an ambulacrum, showing the side plates meeting in the middle line, tear-shaped outer side plates (on the right side only), large pores, and the transverse grooves on the deltoid plates corresponding to them. ×12. 36

Fig. 18. Portion of another ambulacrum, with outer side plates on both sides. ×12. . 56

ELÆACRINUS LUCINA, *Hall*, var. CANADENSIS, *Montgomery*, var.

Fig. 19. Anal interradius, showing the position of the anus, and the posterior deltoid divided by the anal plate. Upper Devonian, Ontario. *Coll. J. G. Hinde.* ×3. . . 36



Berjeau & Highley del et lith.
West, Newman & C^o. imp.

Codaster. Cryptoschisma. Pentremites.
Troostocrinus. Orophocrinus. Tricœlocrinus. Elæacrinus.

PLATE XIX.

Stephanocrinus [illegible] Hall, sp., p. 301.

		Page
Fig. 1.	Summit view showing the modified [illegible], and [illegible] to it the [illegible] [illegible]. Carboniferous Limestone, Belgium. ×[illegible]	1[illegible]

Brachiocrinus [illegible], Meek & [illegible].

Fig. 2.	Cross section of [illegible] body [illegible] lower end, showing three of the ambulacra with the [illegible] plates and the [illegible]. Lower Devonian, Kentucky. Coll. Wachsmuth. ×3.	8[illegible]
Fig. 3.	Another section, taken [illegible] the summit, with four groups of hydrospires. Coll. Wachsmuth. ×[illegible]	[illegible]
Fig. 4.	Radial view of an [illegible] calyx, showing a radial [illegible] with [illegible] the [illegible] [illegible], and two [illegible] plates visible. Coll. Wachsmuth.	[illegible]
Fig. 5.	View of the [illegible] taken in the same specimen, showing [illegible] modified [illegible] [illegible] basal plate (hidden). ×[illegible]	[illegible]
Fig. 6.	Summit view of the same specimen, showing [illegible] regular [illegible] and the modified [illegible] one, [illegible] ×[illegible]	[illegible]

[illegible] Vanuxem, [illegible], sp., p. 316.

Fig. 7.	Cross section of [illegible] from above, showing the [illegible] of the water-vascular ring, the [illegible] leading from the [illegible] to the groups of hydrospires, and the [illegible]. [illegible] Limestone, Kentucky. Coll. Wachsmuth. ×[illegible]	31[illegible]

[illegible] [illegible] Conrad.

Fig. 8.	Summit view of an individual in which the [illegible] processes and the [illegible] plates of three [illegible] have been removed; the [illegible] [illegible] [illegible], and the [illegible] [illegible] are visible. Niagara Group, North America. Coll. W. [illegible]. ×[illegible]	[illegible]
Fig. 9.	Another specimen with the [illegible] processes more or less preserved [illegible] [illegible] plates, with the [illegible] plates of the summit, which [illegible] [illegible] [illegible], and also the [illegible] plates, are [illegible]. Niagara Group, New York State. ×[illegible]	7[illegible]
Fig. 10.	Another specimen similar to Fig. 9, but with [illegible] preserved [illegible]. ×[illegible]	[illegible]
Fig. 11.	Radial view of a [illegible] with [illegible] processes partly preserved. The [illegible] [illegible] are well shown. ×[illegible]	1[illegible]
Fig. 12.	An [illegible] and [illegible] view of a portion of the summit of the same specimen, to show the [illegible] [illegible] [illegible] the [illegible] processes and [illegible] on the [illegible]. ×[illegible]	[illegible]

[illegible] Wachsmuth, W. & S. [illegible]

Fig. 13.	[illegible] view of a well preserved specimen, [illegible] the [illegible] [illegible] and [illegible] with [illegible]. [illegible]. Coll. [illegible]. ×[illegible]	1[illegible]
Fig. 14.	Base of the same specimen, showing the three [illegible] in the [illegible] of the [illegible]. ×[illegible]	1[illegible]
Fig. 15.	Summit view of the same, showing the position of the [illegible] plates, [illegible] and anus. ×[illegible]	11[illegible]
Fig. 16.	The anus and its [illegible] [illegible], with [illegible]. ×3.	11[illegible]

PLATE XIX.

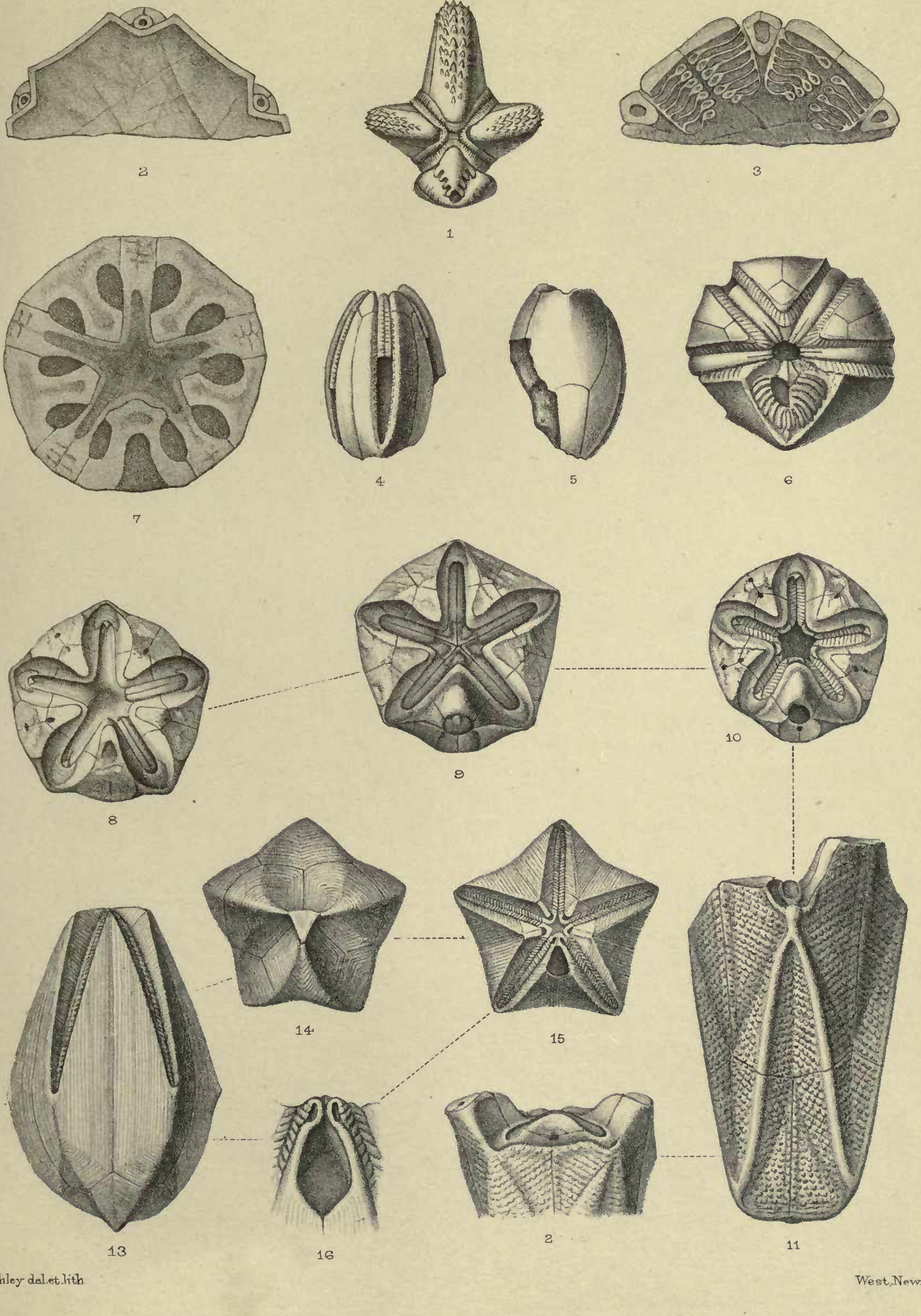
ASTROCRINUS BENNIEI, *Eth. Jn.*, sp., p. 301.

ELEUTHEROCRINUS CASSEDAYI, *Shumard & Yandell.*

ELÆACRINUS VERNEUILI, *Troost*, sp., p. 216.

STEPHANOCRINUS ANGULATUS, *Conrad.*

TRICŒLOCRINUS WOODMANI, *M. & W.*?



Berjeau & Highley del.et.lith West,Newman &

Astrocrinus. Eleutherocrinus.
Elæacrinus. Stephanocrinus. Tricœlocrinus

PLATE XX.

ARCHAEOCIDARIS [illegible], p. [illegible].

PAGE

Fig. 1. Inferior aspect of a specimen in which the small basal plate has been retained; the abactinal radial to be seen below, and the irregular interradius above. Carboniferous Limestone, Yorkshire. ×6 . . . . [illegible]

Fig. 2. A radial view of the same specimen, with one ambulacrum, and two radio-deltoid sutures visible. ×6 . . . . [illegible]

[illegible], p. [illegible].

Carboniferous Limestone: [illegible], &c.

Fig. 3. Exterior view of a radial plate, showing the edge and lip. ×12 . . . . . [illegible]

Fig. 4. Interior of the same plate, with traces of the hydrospires; Fig. 6. ×10 . . . [illegible]

Fig. 5. A deltoid plate as seen from above, surrounded by an arrangement of two of its interradials seen from the side, with the apex of the spine, on which is visible the perforation for the attachment of a spine. ×10 . . . . [illegible]

Fig. 6. Side view of a long interradial process. ×10 . . . . [illegible]

Fig. 7. Summit view of a specimen in which the ambulacra are more or less preserved. ×12 . . . . [illegible]

Fig. 8. Under view of an example ornamented with small pointed tubercles. ×12 . . . [illegible]

Fig. 9. Summit view of a small specimen, with the irregular interradius much prolonged, and the ambulacra removed. ×10 . . . . [illegible]

Fig. 10. Under view of the same individual. ×10 . . . . [illegible]

Fig. 11. Summit view of a similar example, but with the five normal ambulacra preserved. ×10 . . . . [illegible]

Fig. 12. Interradial view of the same specimen, with two ambulacra in situ, and an interradial and a radio-deltoid suture visible; [illegible] are also shown. ×10 . . . . [illegible]

Fig. 13. Under view of the same specimen, exhibiting the irregularity of the basal plates. ×10 . . . . [illegible]

Fig. 14. Summit view of a distorted specimen seen rather obliquely. ×8 . . . . [illegible]

Fig. 15. The azygos radial, showing the two irregular bands below, and the modified radial [illegible] on them. ×8 . . . . [illegible]

Fig. 16. View of a fifth-rayed individual, with the irregular interradius forwards, and the radio-deltoid sutures well shown. ×8 . . . . [illegible]

Fig. 17. Exterior of one of the [illegible] plates, which are next to the azygos radial. ×10 . . . . [illegible]

Fig. 18. Interior of the same plate, with traces of the imbedded hydrospires. ×10 . . [illegible]

Fig. 19. Exterior of the azygos radial, with its notch-like [illegible]. ×10 . . . [illegible]

Fig. 20. Interior of the same plate, with traces of imbedded hydrospires. [illegible], Scotland. ×10 . . . . [illegible]

PLATE XX.

Astrocrinus tetragonus, *T. & T. Austin*, sp., p. 300.

Page

Fig. 1. Inferior aspect of a specimen in which the small basal plate has been removed; the abortive radial is just seen below, and the irregular interradius above. Carboniferous Limestone, Yorkshire. ×6. 26

Fig. 2. A radial view of the same specimen, with one ambulacrum, and two radio-deltoid sutures visible. ×6. 26

Astrocrinus Benniei, *Eth. Jn.*, sp., p. 301.
Carboniferous Limestone, Haddingtonshire, Peeblesshire, &c.

Fig. 3. Exterior view of a radial plate, showing the sinus and lip. ×10. 26

Fig. 4. Interior of the same plate, with traces of the hydrospires, Fig. 3. ×10. . . . 96

Fig. 5. A deltoid plate as seen from above, accompanied by an enlargement of one of its tubercles seen from the side, with the apex of the same, on which is visible the perforation for the attachment of a spine. ×10 302

Fig. 6. Side view of a long interradial process. ×10 301

Fig. 7. Summit view of a specimen in which the ambulacra are more or less preserved. ×12 299

Fig. 8. Under view of an example ornamented with acute prickly tubercles. ×12 . . 296

Fig. 9. Summit view of a small specimen, with the irregular interradius much produced, and the ambulacra removed. ×10 302

Fig. 10. Under view of the same individual. ×10 300

Fig. 11. Summit view of a similar example, but with the four normal ambulacra preserved. ×10 299

Fig. 12. Interradial view of the same specimen, with two ambulacra *in situ*, and an interradial and a radio-deltoid suture visible; an enlarged tubercle and spine are also shown. ×10 302

Fig. 13. Under view of the same specimen, exhibiting the irregularity of the basal plates. ×10 299

Fig. 14. Summit view of a distorted specimen, seen rather obliquely. ×8 302

Fig. 15. The azygos radius, showing the two irregular basals below, and the modified radial resting on them. ×8. 26

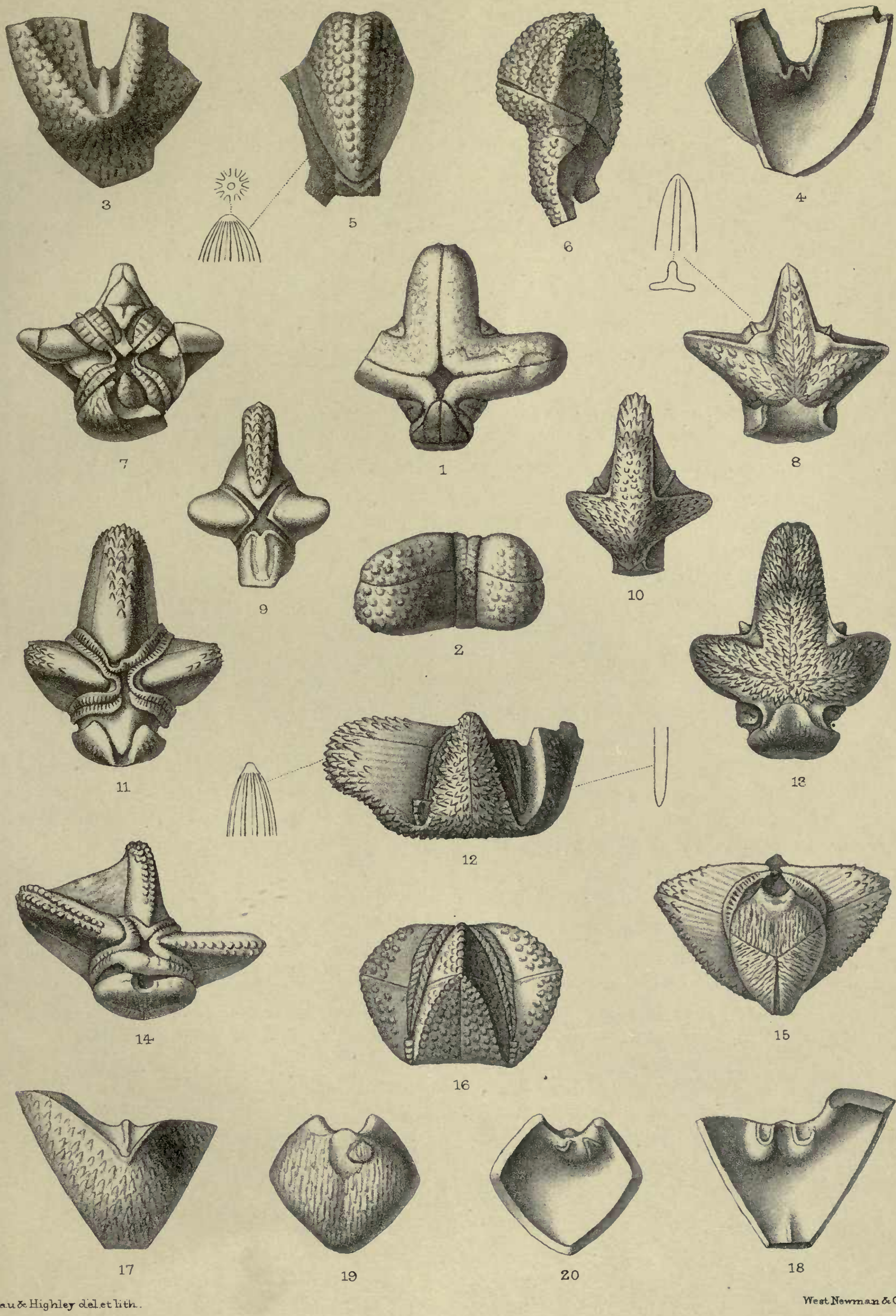
Fig. 16. View of a little-crushed individual, with the irregular interradius forwards, and the radio-deltoid sutures well shown. ×8 302

Fig. 17. Exterior of one of the incomplete radial plates, which are next to the azygos radial. ×10. 26

Fig. 18. Interior of the same plate, with traces of two imbedded hydrospires. ×10. . . 96

Fig. 19. Exterior of the azygos radial, with its notch-like sinus. ×10. 26

Fig. 20. Interior of the same plate, with traces of imbedded hydrospires. *Coll. Geol. Survey, Scotland.* ×10 96



Berjeau & Highley del. et lith. West Newman & Co. imp.

Astrocrinus.

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Storage